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Deliverable D3.2v3: Economic analysis, dark fibre usage cost model and model of operations

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Abstract

The Deliverable presents the results of SEEFIRE project, which represents traditional approach to fibre network budgeting and economic analysis. Based on SEEFIRE project and NREN development in its beneficiary countries in South-East Europe it was recognized, that the main barrier for NREN development is the low level of funding from the state or public budget. For this reason, the economic analysis in this Porta Optica Study Deliverable is concentrated on proved cost advantages of using new photonic technology in wide area networking. It is published for the first time in such detail and also a comparison with traditional approach is made. Mixed photonics and traditional approach is also possible and was proved by CESNET and SWITCH. Budget recommendations for beneficiary countries are made in dependence on recognized local possibilities. Important recommendations for state governments in the beneficiary countries as well as for EC are given. Deployment of photonic industry products in research wide area networks should be supported as the first step of technology transfer to photonics deployment in communications.

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1 Introduction

This deliverable provides the results of the analysis of economic issues of fibre network deployment and operations. It also contains suggestions for the financial rules governing the building and operation of the networks that should be implemented in the beneficiary countries (as it was agreed by project partners).

Dark fibre NREN is a relatively new concept and should be well understood in order to properly evaluate the economic aspects of such infrastructure development. Fibre acquisition and operations involve new cost categories that have to be recognized and added to the economic model of operations of future fibre based NRENs. Also the economic assessment shall be done for a longer period – the dark fibre is usually a long-term acquisition and shall be evaluated as such.

The NREN self-interconnection is already used within i.e. NORDUNet but still there are certain economic implications of international dark fibre interconnections, which have to be well understood for successful deployment. Similar issues are now being investigated in GÉANT2 project (so called Cross Border dark Fibre – CBF concept) and Porta Optica Study have received a direct feedback from the involved partners (CESNET and PSNC) – CBF connection is already in service between NRENs of Austria, Czech Republic, Poland and Slovakia. This countries use transit over self-interconnection CBF extensively (peak traffic is over gigabit per second in most days) and their experience and approach are included here.

This deliverable also analyses the first results of research of new photonic technology application in wide-area networks. This results show, that deployment of advanced programmable photonic devices in suitable research and education networks in POS countries opens new possibilities in network applications, network manageability (for example by using open software) and substantially lowers the costs. Deployment in new dark fibre networks can be simpler than in legacy networks and will give more experience. This idea was discussed in more details in Porta Optica Study workshop in Kiev [1], in [11] on 4th International Open access workshop [15] with Africa's UBUNTUNET experts and with highly experienced experts of U.S. Regional Optical Networks (RONs) in the QUILT alliance workshop in Salt Lake City [12, 14], with positive feedback.

A new area of collaboration of NRENs with photonic industry and photonics research clusters [21, 22, 23] appears, because NRENs and especially their experimental facilities are naturally the first application area for new photonics products and prototypes in wide-area networking. **For general context and EU support of photonics you can see presentation of Viviane Reding, Member of the European Commission responsible for Information Society and Media** [25].

First experiences concerning deployment of new products of photonic industry in national research and educational networks were acquired by CESNET in collaboration with ACOnet and SANET and by some other European NRENs (especially by SWITCH).

This Deliverable is based on the Description of Fibre footprint database and connectivity used by NRENs in target countries, which was collected for Deliverables D2.1 and D3.1 [10].

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2 SEEFIRE project results in economic analysis and dark fibre usage cost models

Deliverable D3.2: Economic Model for the Acquisition and Operation of Dark Fibre Networks in SE Europe was elaborated in SEEFIRE project. This document is publicly available [2] and considers the contractual parameters associated with the acquisition of dark fibre, both from a technical and financial point of view, based on the experience of procuring dark fibre as part of the GÉANT2 project. To assist in the development of budgetary estimations, two cost modelling tools are described.

The first model provides a simple budgetary tool based on route length, to calculate an approximate cost of lighting any dark fibre route.

The second model, derived from the work carried out in the GÉANT2 procurement, enables more detailed comparisons of different routes. It also concerns the question of dark fibre usage in research and education networks and its economic justification. It was a "big question" in the time of GÉANT2 preparation and procurement, despite the previous decisions of many European NRENs to use dark fibres. The difference was seen mainly in distances to be overcome by fibres. An important question was if it is more cost effective to lease fibres compared to leasing some number of lambdas. It is very difficult to say, what number of lambdas will be needed for given line in the future - assumptions could be misleading. Despite this difficulty, the second SEEFIRE model gives some insight into the details of this issue. Indirect result of this comparison is the "technical feeling", that fibre lighting problems should be solved by transmission systems allowing relatively cheap step-wise extensions and improvements, and not by systems in which additions of lambdas and changing the maximum acceptable number of lambdas is expensive.

In the time of writing POS project, it was was widely accepted that research networks should be based on dark fibres, and project inquired if it was possible. An indirect confirmation of this strategic decision is, that no NRENs using dark fibres and CBF move back to buying lambdas from capacity providers.

A number of national scenarios using the simple model are attached in this SEEFIRE document to give an indication of the likely budgetary costs associated with lighting fibre in the region. From today's point of view it is needed to update costs used. It is also necessary to use costs relation valid for POS countries and take into account new results of photonic industry. This is done in following text in detail - new cost tables are collected and new calculation tables are developed.

SEEFIRE project results in conviction, that the main barrier of NREN development is low level of funding from the state or public budget. This means the budgets suggested in chapter 6 should be as economical as possible and step-wise improvements of topology and equipment should be implemented. Cost lowering should be achieved by using dark fibres and advanced photonic technology.

National support of NRENs development should be understood as a priority for the governments and parliaments of the beneficiary countries. **To help policymakers understand the nature of the new innovation economy and the types of public policies needed to drive innovation, productivity and broad-based prosperity** for their beneficiary countries it is recommended that they read the Information Technology and Innovation Foundation "Digital Prosperity" report [27] .

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3 Cost of dark fibre footprint

3.1 Factors affecting the cost of the dark fibre footprint

A list of parameters affecting contracting dark fibre is provided by Deliverable 3.2 of the SEEFIRE project [3]. In this section this list is re-evaluated and further expanded.

3.1.1 Length of fibre footprint

Typically, the cost of the dark fibre footprint is linearly connected to the length of the dark fibre infrastructure. Moreover, the cost of dark fibre footprint per fibre kilometre is considered to be a metric that provides a reliable indication of the cost effectiveness of dark fibre acquisition.

3.1.2 Maintenance and failure recovery terms

It is usually very difficult for a NREN to be responsible for the maintenance of the dark fibre footprint. This is not only because of the lack of relevant technical expertise but mainly because numerous personnel is required and in many cases expensive equipment. Moreover, for restoring submarine fibre cuts, a ship with specialised equipment must be hired to fix the problem. Usually DF owners outsource this task to relevant companies.

For these reasons, NRENs include maintenance services as a part of the dark fibre contract. The failure recovery terms (e.g. upper limit on restoration time) have direct impact on the cost of the fibre footprint.

3.1.3 Collocation

After dark fibre infrastructure is acquired, a NREN has two options: either to deploy DWDM transport equipment or to use well-known layer 2/3 equipment with long reach interfaces. In most cases collocation is required not only at the nodes where NREN clients are aggregated, but also at the nodes that serve for regenerating/amplifying the optical signal. In this case, NRENs must include collocation services in the dark fibre contract. The collocation services' cost increases linearly with the number of collocation nodes.

3.1.4 Number of fibres

Usually DF contracts have to operate on a pair of fibres. However, it is technically feasible and cost effective to transport bidirectional CWDM or DWDM lambdas over a single fibre, using two wavelengths for a bidirectional lambda – one for each direction. The overall number of wavelengths for transmission in a fibre is technically and physically limited, but existing fibre lines are seldom full.

It is also possible that a NREN acquires a contract for more than one pair of DF. In this way, a NREN does not need to deploy WDM equipment but just to activate an extra pair of fibres every time additional capacity is required. Cost effectiveness of this approach strongly depends on the costs of additional fibre pairs. It can be effective, if a new cable line is constructed for NRENs (the cost of line and the maintenance cost are nearly the same for a different number of fibres), but probably not if a NREN leases fibres.

To sum up, acquiring a single pair of DF and deploying DWDM transport equipment is the most usual solution. Using single fibre seems to improv for cost effectiveness for fibre lessees. The cost of single fibre lighting and the reliability of transmission are discussed in next chapter.

3.1.5 Duration of the contract

Typically, smaller cost of dark fibre footprint per fibre kilometre is achieved in long term dark fibre contracts compared to shorter term contracts.

3.1.6 "Geography" of the fibre footprint

Not all fibre links cost the same, according to "supply and demand" rule. More specifically, fibre links connecting high population cities are expected to cost less than submarine links connecting low populated cities. In the former case DF supply is expected to be greater and this lowers the prices.

3.2 Dark fibre contracting methods

3.2.1 Long term IRUs

An Indefeasible Right of Use (IRU) is a contractual arrangement with which an "IRU user" can unconditionally and exclusively use one or more fibres of the "IRU grantor's" fibre network for a long time period (typically 10 to 25 years). The wholesale purchase of dark fibre has normally been accomplished by means of IRUs.

The IRU contract defines detailed technical and performance specifications for the IRU fibres. More specifically, it includes DF acceptance and testing procedures, the description of the DF physical route, operating specifications for the DF infrastructure, performance specifications (attenuation, Chromatic Dispersion, Polarisation Mode Dispersion, Optical Return Loss), maintenance and restoration terms. These terms must be valid for the full duration of the IRU contract. Moreover, it includes specific actions and procedures in cases of changes on the IRU grantor's fibre network, degradation of fibre performance etc.

In case the IRU grantor is not the owner of the real property where the fibres are located, the IRU should include agreements with third parties (e.g. rights-of-way) that authorise the use of the DF infrastructure.

Note that the IRU user is solely responsible for repairing and maintaining the active/passive equipment that is connected with the IRU fibres.

Due to the long term perspective of the IRU contract, it should include the case when the IRU grantor falls to bankruptcy or even the case of mergers or acquisitions. In the former case the IRU user must have the right to terminate the contract and in the latter case the IRU contract must be automatically transferred to the company that currently owns the IRU grantor under the same terms.

IRU payment terms usually follow the scheme outlined below:

- A lump sum payment corresponding to the DF construction cost and the use of the DF infrastructure for the IRU duration. This payment usually accounts for the greatest part of the IRU budget.
- A periodic (e.g. annual) fee corresponding to the maintenance services provided to IRU user by the IRU grantor. This is usually fixed or slightly increasing, taking into account country's inflation.

IRU is probably more used in US than in Europe. For long-haul fiber the price of FiberCo for research networks is $850/strand mile for 20 year IRU with front payment and 200/route mile for annual O&M [4]. It is about 0.2 Euro/meter/year (E/m/y) of strand (fibre) pair cost, including time value of front payment instead of value (see 5.1.7). **Fibre acquiring costs for research networks in Western and Central Europe are usually 0.1 – 0.4 E/m/y, in other parts of Europe there are higher (up to about 1 E/m/y).**

IRU is considered an asset in some countries and IRU front payments is CAPEX, so in the tax calculation only annual depreciation is taken into account, resulting potentially in higher tax payment (but tax calculation depends on annual lost and profit sheet of an organisation, possible national tax exceptions for non-profit activities etc.). Based on those tax rules, separation of IRU and O&M payments in contracts are inevitable.

In many European countries that separation is not necessary, because IRU is not recognized as a special case in the law system and in the tax rules. It is then contracted as a long term fibre lease including O&M. In some cases it is possible to obtain support for cable line construction from EU Structural Funds and to use IRU-like contract to support a NREN in given region (see presentations in SEEFIRE Policy workshop, 2006 in Bucharest [5, 6]).

3.2.2 Leasing of dark fibres

Pre-procurement knowledge

On the basis of the previous projects and internal experience, we decided what knowledge about existing and available fibres and services is important in preparation of procurement, decision and contracting dark fibre leasing (see [8], Chapter 3.3)

Leasing of dark fibre in CESNET

CESNET has leased the first pair of dark fibres between the biggest towns of Czech Republic Praha and Brno since 2000. The contract was with a fibre owner company – an oil transit company. The subject of contract is research cooperation (evaluation of some new usage possibilities, etc.). The fibre line Praha-Brno was operational in CESNET before telecom market liberalization in the Czech Republic (research cooperation is not supposed to be telecommunication service, so different laws and statutory regulations are used).

CESNET consists of 4.830 km leased dark fibres including 370 km of single fibre lines now. Dark fibre lines are contracted with an oil transit company, a railway company, a network infrastructure provider and telecommunication companies. Diversification of fibre leasing to about 8 fibre lessors is proved to be an economical advantage for CESNET, including more labour needed for contracting. Important advice is to have one provider for one PoP to PoP line, but also to obtain information about the owners of subcontracted fibre segments.

Procurement, contracting and paying CBF

CBF lines are very important parts of an advanced NREN. Acquiring and maintenance of CBF lines is not very easy, because the line is placed between two neighbouring NRENs, in two neighbouring countries and mainly because both partners participate in procurement, contracting and paying. We must suppose, the rules for procurement can be different in these countries and that the rules depend on expected contract cost. Collaboration of lawyers could be needed to recognize, what type of procurement, contracting and payment is acceptable and fair for both partners in difficult cases. Fortunately, many cases are simple.

CESNET uses three CBF lines presently.

The first dark fibre line built since 2003 was **Brno (CZ) - GE Bratislava (SK)** over 190km. This line has used new advanced photonic products CLA PB01 with the 4-channel DWDM Mux/demux since February 2006. CESNET contracted to lease Czech part of this dark fibre line Brno – Hrusky near the CZ – SK border with network infrastructure provider for indefinite time. The price of leasing covers maintenance as well. Slovak NREN SANET has leased dark fibres from Hrusky to Bratislava from the same provider. Each NREN covers its own expenses. In the initial stage, a switch was deployed in Hrusky and each NREN was monitoring its own part of line. Now there is no equipment in Hrusky and each NREN is monitoring the whole line by CLA.

Ostrava (CZ) - Cieszyn (PL) line, which is about 74 km long has been in operation since 2004. This line has been equipped with DWDM 32 x 10 Gb/s. CESNET has leased the Czech part (71km long) of Ostrava –

Cieszyn line from telecommunication company. Maintenance of the Czech part is included in monthly price of leasing. Polish dark fibres of this CBF line are the property of PSNC. This means that each country covers of expenses for dark fibre exactly "each up to border". Monitoring of CZ – PL CBF is different: CESNET DWDM equipment is housed on Polish side in Cieszyn and connected to Pionier DWDM equipment, so that CESNET is monitoring whole line. In addition, CESNET and PSNC have implemented monitoring for the new GEANT2 lambda **Praha-Poznan** (along that CBF) in CESNET2 network and in Pionier network.

Another CBF line: **Brno (CZ) – Vienna (AT) (**approximately 224 km long), has been equipped with a new type of CLA PB02 optical amplifiers and started in the middle of 2006 year. Contracting and building this CBF was more difficult and the time spent on discussing it was longer in comparison with other lines. CESNET has contracted the whole line and is covers all expenses. Brno – Vienna consists of three segments of dark fibres from two providers. It was necessary to negotiate with two providers and to arrange a connection of three segments. To use one master provider subcontracting others was not possible for commercial reasons. Some problems appeared concerning appointing the right connecting place and measuring the whole line (one fibre provider was not prepared for long NIL solution from a technical point of view). CESNET monitors the whole line. The line is used mostly for IP connections between CESNET and ACOnet and between Pionier and ACOnet, including very important cost effective peering in VIX for commodity Internet access.

The routes Brno – Bratislava, Brno – Vienna and Slovak CBF Bratislava – Vienna are create the first cross border dark fibre triangle. More details can be found at [17].

In summary, the procurement, contracting and monitoring of CBF can be more difficult than leasing fibres in a single domain, although it is very important for the improvement of NREN services and contributes lowering the costs. High level of traffic on CBFs can be seen on [9].

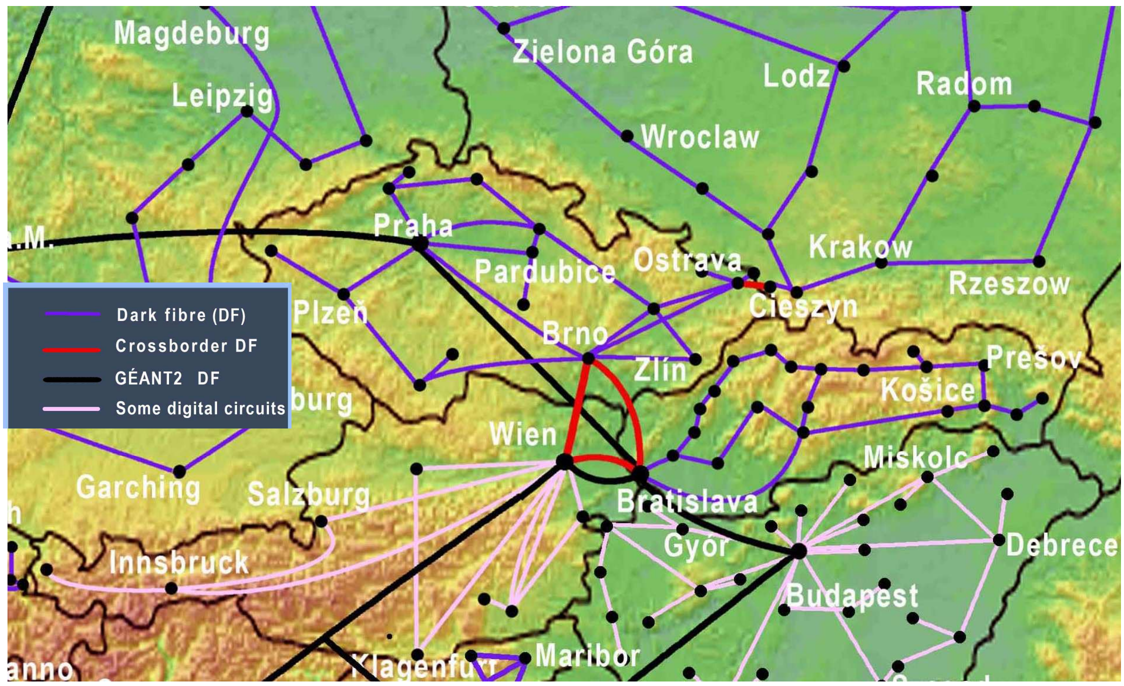

Figure 3.1: The first cross border dark fibre triangle

An example of the cross border connection in SEE countries can be Subotica – Szeged line (Serbia - Hungary).

A dark fibre line between Subotica and Szeged was established in the second half of October 2005. The dark fibre pair is approximately 52km long: approximately 32km in Serbia and the rest in Hungary. The dark fibre is leased by AMREJ/University of Belgrade from two operators, Telekom Srbija, on the Serbian side and Pantel on the Hungarian side.

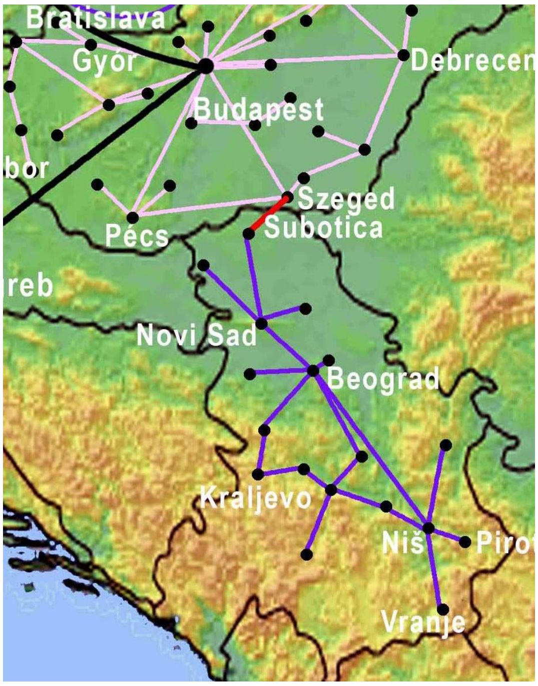

Figure 3.2: Cross border dark fibre connection Subotica – Szeged

CBF connection between NREN in Serbia and NREN in Bosnia and Herzegovina, as well as fibre footprint required in SEEFIRE and SEEGRID2 EU projects is presented in [11]. This CBF is used for GEANT2 access and commodity Internet access, too.

GEANT2 lambdas over NRENs CBFs

GÉANT started using dark fibre use in 2005. GÉANT2 network uses dark fibre connections of GÉANT PoPs located in NRENs' central PoPs (usually in the capitals). All GÉANT2 dark fibres that cross the borders are about 110 – 2000 km long, and are not called CBFs (CBF should be short connection between neighbouring NREN PoPs close to border). GÉANT2 dark fibre footprint overlays national dark fibre footprints.

GEANT2 started using CBFs in 2006. CBFs are installed by NRENs and used for GÉANT2 lambda services (in part or fully) [24].

Motivation:

- Installing cost-effective lambdas between GÉANT2 PoPs for which GÉANT2 dark fibres are not available (for example Poznan, Poland)
- Using optimal connections for some important projects (for example ATLAS)

CBF Based Services — Service Types

Service	Description
Type A	Wavelength provided between GN2 PoPs
Type B	Wavelength provided for projects, bypassing GN2
Type C	Bilateral services independent of GN2

Figure 3.3: Types of CBF services

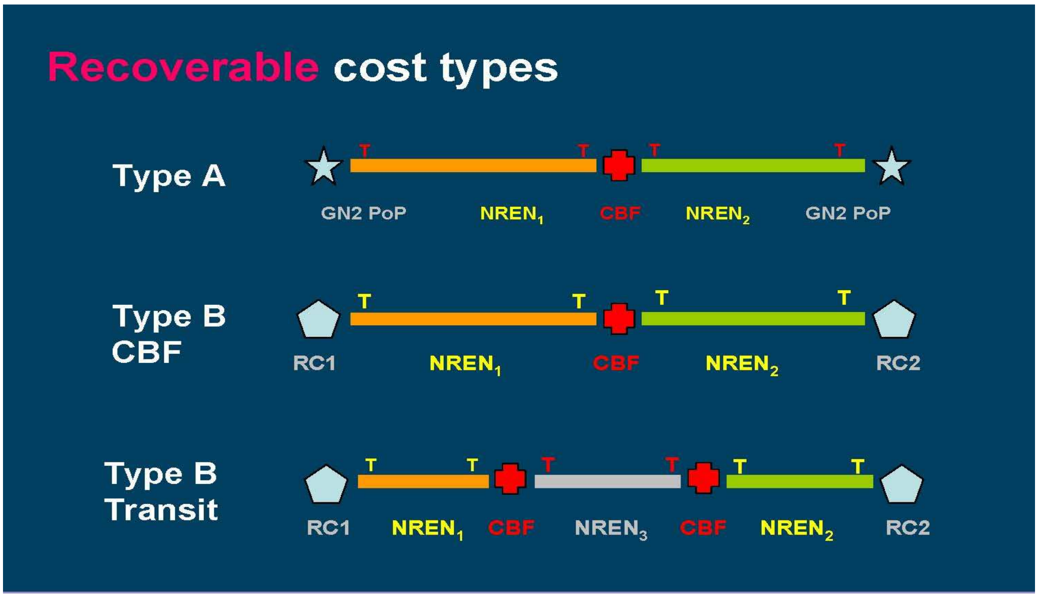

Figure 3.4: Recoverable cost types supported by GN2 project

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CBFs are used in GN2 project e.g. for implementing 10G lambdas between GEANT2 PoPs (type A in GN2):

- Cieszyn (PL) – Ostrava (CZ) for Prague-Poznan
- Frankfurt a.O. (DE) – Slubice (PL) for Frankfurt a.M.- Poznan

CBFs are used for implementing 10G lambda connections for projects supported by GN2 (LHC, DEISA) as well (type B in GN2):

- Como (IT) – Manno (CH)
- Basel (CH) - Kehl (DE)
- Kehl (DE) – Strasbourg (FR)
- Enschede (NL) – Münster (DE)

Type C are CBFs not used in GEANT2 network, but usually very useful for NRENs.

Fibre maintenance

Fibre maintenance services are included in dark fibre contracts as shown in chapter 3.2.4. The lease price often covers fibre maintenance. Taxation usually does not require separation of the lease cost and maintenance cost, if both are paid recursively.

Monitoring by provider staff

Provider staff monitor dark fibre lines and CESNET has its own monitoring staff as well. If contracted monthly availability of the line is e.g. 99.7% and the availability is lower, then the penalties can be up to 100% of the monthly payment.

Building of missing last miles

The bottleneck in providing high speed E2E services is the last mile. Acquiring and contracting building of last miles is a very important part of tendering process. Not all DF providers offer fibres to demanded locations, including subcontracting with metropolitan providers. There are more possible last mile solutions. The provider builds missing part of the fibre line or delivers cheaper last mile microwave technology. Constructing the line using microwave or free space optics could be a good solution until all dark fibre lines are built. A typical price of laying dark fibre cable for one kilometer is about 41.700 Euro. For comparison: one 10Mb/s microwave link costs about 338 Euro, 34Mb/s link costs 1.190 Euro, 100Mb/s link costs 1.390 Euro and link lengths can be up to about 40 km, but direct visibility is needed.

CESNET has acquired one provider capable of building last dark fibre lines and have contracted building and lease of dark fibre circuit since 2002. The example of contract document (see [3], Appendix 1, Chapter 9.1.2.2) includes an article which mentions the right to use optical fibres in the last mile based on setup (installation) fee. “The lessee is bound to pay an installation fee at the rate of 70% of the installation costs for the setup of the ordered last mile. These costs will be mentioned in the setup budget in the offer and consequentially in the technical specification, in the Attachment no. 1. The lessor is bound to reserve 70% of optical fibres in such last mile for the lessee’s use. The remaining cost at the rate of 30% of installation costs for the last mile setup, is the duty of the lessor. The lessor has thus the right to reserve 30% of optical fibres in such last mile for the lessor´s own use." Usually 24-48 fibre cables are used, because the setup fee increases with the number of fibres slowly and the availability of fibres between university premises or NREN PoP to near by fibre meeting point is very important. Another reason for building the last mile fibre cables is to have physical diversity to a PoP or improvement of reliability (fibre outages like cuts cannot be sometimes repaired quickly and penalization is not able to solve such issues).

Tender and contract documentations

Procurement and contract documents used for a dark fibre tender and contract and for a transmission equipment tender and contract provided by GRNET, CESNET and DANTE are included in [3], Appendix 1.

CESNET uses two other procurement documents for mixed dark fibre and capacity tenders now:

- Call for the lease service of a circuit 10 Mb/s – 1 Gb/s (see Appendix D), important for end users
- Call for the lease of fibre or lambda (see Appendix E), important for connection of NREN PoPs.

In general, it is difficult to compare the offers of fibre lease with the offers of lambda service, if it is not sure (as usual) how many lambdas will be needed in contract duration. In such cases, CESNET presumes 6 lambdas in the quote criteria (see Appendix E).

3.2.3 Purchasing or building fibre infrastructure

PIONIER (Polish Optical Internet) network is being built using several different technologies and different legal status concerning the ownership of fiber infrastructure. Below several models of building fiber network taking into account PIONIER experience are briefly described:

a) Fibres in a cable shared with another operator

Based on the agreement, PIONIER consortium purchased several fibres in the cable of another provider. The agreement defines responsibilities and terms of use of the infrastructure. PIONIER incures the costs of maintenance, operation and failure recovery. The cable owner is responsible for assuring trouble-free operation. Underground cables and overhead cables along power distribution lines are used. PIONIER transmission equipment is located in the premises of the fiber owner, in separate racks with independent power supply. According to the agreement with another provider PIONIER workers have unlimited access to this transmission equipment.

b) Own cable installed on high-voltage power lines

Based on the agreement with the Polish power industry (owner of power distribution lines infrastructure) OPGW (Optical Ground Wire) cables and ADSS (All-Dielectric Self-Supporting Aerial Cable) cables were installed on high-voltage (110kV) power distribution lines. In return, PIONIER network operator provides the power industry with the access to some number of fibres. Maintenance, operation and failure recovery is outsourced to the power industry.

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c) Own cable built along railways

PIONIER consortium possesses ‘right of way’ from the Polish railways which allows to construct its own underground cables along railways. Maintenance, operation and failure recovery is outsourced to an external telecom company.

d) Own fibre infrastructure built together with another operator

To limit the cost of building of PIONIER’s own fibre infrastructure the investment was conducted with another operator who also needed fibres along the same route. According to the agreement such an operator is responsible for maintenance, operation and failure recovery.

e) Fibre lease

PIONIER consortium leases (20 years lease time) some fibres from third party operators. The lease price contains fibre maintenance, possibility of installing and unlimited access to PIONIER equipment.

3.3 A review of the DF contracting methods at NREN networks

In the table below the DF contracting methods used at several NRENs worldwide are shown. There is not a single DF contracting method that is widely used; this could be explained by the different national laws it the target countries leading to a specific contractual method. In all cases maintenance services are included it the DF acquisition contract and in most cases these are long-term contract.

NREN	Country	Contracting Method	Duration (years)	Dark Fibre footprint (km)	Maintenance services included
BiharNET	Bosnia-Herzegovina	Leasing	2 (optional extension)	450	Yes
CESNET	Czech Republic	Leasing	4 (+6 optional)	4.830	Yes
FCCN	Portugal	Owned	-	48 pairs x 360	Yes - outsourced
GEANT2	UK	Leasing	3 (+7 optional)	12.000	Yes
GRNET	Greece	IRU	15	6.000	Yes
Internet2	USA	Leasing	7	21 000	Yes
NLR	USA	IRU	20	18 500	Yes
PSNC	Poland	Owned	-	3 800	Yes – outsourced

PSNC	Poland	Leasing	20	500	Yes - outsourced
Surfnet	Netherlands	IRU	15	6.000	Yes
SWITCH	Switzerland	IRU, leasing, co-ownership	5-25	2.125	Yes

Table 3.1: DF contracting methods at different NRENs

4 Cost of photonic transmission

4.1 Innovative approach to lighting of research network

Recently one of the biggest breaks in NRENs design and scheduling has been caused by the transition from leased “telco” services to dark fibers. This step has allowed NRENs to benefit from the same features as “telco” operators (e.g. WDM). NRENs are able to deliver more services at more reasonable costs to their members or customers. However, this step brings a necessity of usage of the transmission equipment.

NRENs are in a slightly different position than “telco” operators, because regular transport WDM network is not an objective for them, it is only a way to transport more data.

Traditional approach (e.g. inline amplification and chromatic dispersion compensation each 80km) is not necessary every time. In principle, transmission equipment eliminates distances among devices of higher layers. This approach is being partially supported by some “digital” optical equipment vendors and is extremely important for situations where some demarcation is inherently needed.

The NRENs market is to small for well established transmission equipment vendors to offer special NREN suitable equipment series. Current typical approach is to deploy and use the available equipment though some NREN useful features are not present and some other features are unnecessary. The worst situation is to be fully dependence on vendor’s research end design life cycles which are not in adjusted to the principles of research networking.

An interesting message is, that some traditional vendors have started discussing the steps needed to offer “software programmability and flexibility required by the research community”, see [18]. It can be helpful, supposing NRENs will continuously keep their independent lighting possibilities important to maintain the low cost level and to be competitive on the market.

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4.2 Photonic design kits important for future NRENs and other CEF Networks

As mentioned above, regular transmission equipment vendors represent normal for profit business organization with equipment design affected by normal life cycles. However, delivering the best possible services and features to R&E community without using the newest and the most advanced technologies is difficult. A possibility of using and deployment of the advanced photonics industry products is one of important factors for photonic design kits. The idea is also supported by the increasing presence of digital interfaces in optronic modules, though the majority of optronic functions are analog based.

An absolutely essential issue of optical transmission is attenuation which can be overcome by optical amplification. Then the first choice is obviously a design kit of optical amplifier. As far as amplification is concerned, it is possible to use different approaches, although the usage of EDFAs (Erbium Doped Fibre Amplifier) and Raman amplification is the most common. EDFA technology was very well mastered in the past and now EDFAs offer high reliability, high gain and reasonable low NF (Noise Figure). One of the drawbacks is quite limited spectral usability of EDFAs. Raman amplifiers, introducing broad spectral usability, very low NF but lower gain and potential presence of high power signals in transmission fibre, can solve the problem.

Once transmission speed has grown to 10Gbps, the necessity to handle CD (chromatic dispersion) appears. Traditional approach means using DCF (Dispersion Compensating Fiber), which is unfortunately quite bulky and lossy. Another approach to CD compensation is presented by using FBG (Fiber Bragg Grating) which introduces lower losses and also tunability in special configurations. As transmission speed and power (caused by many channels and large distances) in the fibre grows, the tolerance of CD receivers falls and the necessity of exact CD compensation appears.

4.3 Devices developed by CESNET

The above mentioned reasons led CESNET to develop its own photonics design kits.

Amplifier kits called CLAs (CzechLight Amplifiers) have allowed CESNET to apply and develop NIL (Nothing In Line) approach easily using remote control and management. CLA devices allow to house up to 4 amplifiers in 1U case easily and to benefit from the best amplifier modules available on the market, reach very low NF and thus overcome longer distances. In comparison with previously mentioned modules, traditional “telco” EDFA types have parameters necessary “just” to overcome typical 80km spans.

A design kit of Raman source designated for Raman distributed amplification in transmission fiber was also developed. This kit is designed to assist EDFA based amplification on extremely long NIL lines.

Exact CD compensation is becoming an issue for 10GE long NIL lines and especially for 40G and higher speed will be crucial. This fact led CESNET to develop a design kit of dual tunable CD compensator using FBGs. The device was designed for laboratory and field use. Remote control and management is available.

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Another tunable CD compensator, using different technology is also considered. It should offer a price effective solution for NIL links at the same time avoiding spans cascading where not so exact CD management is needed.

4.4 Costs of photonics transmission for budgetary purposes

Following tables summarizes the prices of transmission equipment in kEUR including also necessary pluggable optics. Prices are presented according to the authors best knowledge. Both passive and active (amplified) technology is considered. For 1GE both CWDM and DWDM technologies are considered. First, the NIL (Nothing in Line) solution costs are shown and then costs of multi-scenarios follow.

4.4.1 NIL transmission on single fibre

fibre km	80	120	160	200
1 x GE	1	1.2	13.7	13.7
2 x GE	3.5	4	17.7	23.8
4 x GE	6.5	7.3	28.8	28.8
1 x 10GE	7.5	26.6	27.3	36.3
2 x 10GE	20.2	37	43.1	46.7
4 x 10GE	51.2	56.9	62.3	73.7
8 x 10GE	89.9	104.9	104.9	112.4

Table 4.1: Single fibre bidirectional NIL transmission (kEUR)

4.4.2 NIL transmission on fibre pair

pair km	80	120	160	200
1 x GE	0.9	1.1	1.4	13.2
4 x GE	5.4	5.7	28.3	28.3
8 x GE	11.5	13.2	42.1	42.1
1 x 10GE	7	26.1	26.8	35.8
4 x 10GE	38.9	55.7	61.8	73.2
8 x 10GE	89.3	104.3	104.3	111.8
16 x 10GE	170.8	183.3	183.3	190.8

Table 4.2: Fibre pair bidirectional NIL transmission (kEUR)

4.4.3 Multi-hop transmission on single fibre

fibre km	2x120	3x100	3x120	4x100
1 x GE	10.5	19.35	31.15	28.2
2 x GE	14.2	23.5	36	32.7
4 x GE	20.7	31.2	31.2	41:7
1 x 10GE	39.4	41.8	53.6	54.5
2 x 10GE	55.9	51.4	70	64.2
4 x 10GE	75.4	89.9	95.8	109.9
8 x 10GE	110	126.2	135.8	141

Table 4.3: Multi-hop single fibre bidirectional transmission (kEUR)

4.4.4 Multi-hop transmission on fibre pair

pair km	2x120	3x100	3x120	4x100
1 x GE	9.7	18.3	30.1	26.9
4 x GE	19	27.6	27.6	39.2
8 x GE	29.9	39.5	39.5	49.1
1 x 10GE	38.3	40.1	51.9	52.3
4 x 10GE	74	87.6	93.5	106.7
8 x 10GE	107.9	122.5	122.5	135.7
16 x 10GE	186.9	201.5	201.5	214.7

Table 4.4: Multi-hop fibre pair bidirectional transmission (kEUR)

4.5 Photonics transmission over CBF and application

CBFs represent a very suitable place for deployment of NIL solutions especially supported by photonic design kits. In fact CBFs typically represent a demarcation point between two –NRENs' domains. So CBF deployed by NIL transmission kits simply put two border devices to one another, without necessity of usage regular transmission system and back to back configuration of demarcation devices. Effectiveness of this approach is indicated e.g. by deployment and operation of AT-CZ-SK CBF triangle, offering also resilience to one edge failure. More details can be found in [17]. Very cost-effective application is also the use of CBFs for commodity Internet access.

Some CBFs are used also for the implementation of lambdas connecting GÉANT2 PoPs or GÉANT2 PoP and a premise important for an application project in a neighbouring country. CESNET and PSNC participate in pilot deployments and their experiences are available to POS target countries.

4.6 Indicative cost of photonic transmission by deploying traditional vendors' DWDM equipment

In this section indicative prices for optical transmission equipment which is available from traditional vendors of network equipment are provided. This is an estimation of POS experts based on the offers received from those traditional vendors in procurements over the last months. The prices do not include network management software and licenses, installation services and maintenance. It must be pointed out that the prices shown below are only indicative and cannot be used in order to accurately calculate the expected total cost of deploying optical transmission equipment over a given fibre footprint. In order to accurately define the total cost more parameters must be specified such as fibre performance characteristics (attenuation, chromatic dispersion), selection of DWDM terminal and add/drop nodes, specification of the maximum number of lambdas to be deployed at the End of Life (EoL) of the optical transmission system etc.

Some notes for understanding the results of the budget table are as follows:

- Every terminal node is equipped with 16 lambda multiplexing/demultiplexing filters.
- For the 200km fibre pair links it is assumed that an intermediate node exists on the middle of the distance among the terminal nodes. No regeneration but only amplification occurs at the intermediate node.
- Contemporary DWDM transport systems typically implement GE framed lambdas over a distance of roughly 100km without amplification. This is usually the case when a small number of lambdas is deployed; when the number of lambdas increases then amplifiers must also be deployed. It was assumed that for up to 8 GE framed lambdas no amplifiers (EDFAs) are required but when 16 GE lambdas are deployed then EDFAs must be deployed at the terminal nodes. This explains the steep increase of the budget when comparing the 8 x GE deployment (100km) with the 16 x GE deployment (100km).
- The same assumption for GE framed lambdas holds for the 200km fibre link case; when the number of deployed lambdas increases to 16, then additional EDFAs must be installed and this increases the cost significantly.
- For the 10 GE lambda scenarios it was also assumed that as the number of deployed lambdas increases, additional amplifiers are required. This limit was considered to be 8 lambdas.
- An important cost factor for 10 GE deployments is that Dispersion Compensation Modules (DCM) must be used. Deployment of these devices affects the total cost in two ways; first their cost is by no mean

negligible and more importantly DCMs increase the real length of the fibre link, hence more powerful amplifiers are required.

- For the 10 GE lambda scenarios and as the number of deployed lambdas increase, the total cost increases in a sharper way when compared with the GE lambdas scenarios. This is attributed to the high cost of 10 Gbps transponders which significantly influences the network's total cost.

Finally, prices are given in kEuros.

pair km	100	200
1 x GE	24.1	39.5
4 x GE	33.5	48.9
8 x GE	42.5	64.1
16 x GE	77.2	92.6
1 x 10GE	58.4	80.8
4 x 10GE	120.2	142.6
8 x 10GE	202.6	225.0
16 x 10GE	379.9	414.8

Table 4.5: Lighting costs estimation based on offers received by traditional vendors in procurements

4.7 Effective usage of photonics technology

Optimal network design begins with a proper link selection. Keep-It-Short (KIS) approach plays an extremely important role reducing the quantity and complexity of the equipment needed and thus both CAPEX and OPEX. However, the offers of fibre line routes and fibres are sometimes very limited and some rescheduling and re-tendering can bring new advantages. As far as transmission equipment it has to be noted that traditional approach still plays important role. Systems are still predominantly designed in one-fit-all manner. As mentioned above, in traditional approach the amplification and chromatic dispersion compensation using compensation fibre is done periodically each 80 km. The necessity of frequent amplification is partially caused by high insertion losses of DCFs, too. Tailored design can bring different advantages e.g. price effectiveness. For example, the shortest distances (≈140 km for 1G) can be handled very easily in a passive manner. Furthermore NIL solutions can be easily deployed for distances up to 200 km (or more in case if lower loss links). This fact plays an important role for CBF links. Longer multi-hop links can also gain from usage of low-loss CD compensating devices does allowing thus longer spans lengths like 120 or 100 km. Tailored designs of new photonic industry products can bring additional advantages to NRENs such as better understanding of design principles, more experience for future network designs and tenders.

Fibre pair	Traditional vendors 100 km	Photonic vendors 120 km	Traditional vendors 200 km	Photonic vendors 200 km	Photonic vendors 4x100 km
1 x GE	24.1	1.1	39.5	13.2	26.9
4 x GE	33.5	5.7	48.9	28.3	39.2
8 x GE	42.5	13.2	64.1	42.1	49.1
1 x 10GE	58.4	26.1	80.8	35.8	52.3
4 x 10GE	120.2	55.7	142.6	73.2	106.7
8 x 10GE	202.6	104.3	225.0	111.8	135.7
16 x 10GE	379.9	183.3	414.8	190.8	214.7

Table 4.6: Traditional vs. Photonic vendors fibre pair lighting cost comparison based on tables 4.2, 4.4 and 4.5 (kEUR)

We can do comparison of lighting costs based on the prices from procurements for some NRENs (i.e. not list prices) in previous tables – see table 4.6. It should be clear, that presented values are not valid in some circumstances – differences can be bigger or smaller. For longer lines the difference could be very large as there are many design alternatives. In these cases, an analysis of real tasks is preferred. The last column indicates that cost effectiveness of open photonic design is not limited to NIL distances.

Reasons for higher prices in traditional vendor's offers can be as follows:

- Technology development road maps don't supporting the needs of research networks adequately (it is small segment of the market)
- Process of incorporating new optical devices in network equipment is slow to save previous investments in research and development
- Price of support is not well separated from equipment price (disadvantage to users having their own design knowledge or independent support)
- Price politics is to move part of routing and switching costs to lighting costs (low cost start and higher cost development for user networks)

Experience shows, that photonic devices are very stable and a user usually needs support in the design phase only.

Important and reliable results from table 4.6 are as follows:

- Every good design of lighting should take into account both possibilities (traditional vendors and photonics vendors)
- For a given fibre line or fibre footprint (having end-to-end fibre lines parameters) is possible to do exact cost comparison based on procurement(s)
- Offers of both competing groups will be improved in the future (competition and quantity of production is supposed to have main influence)

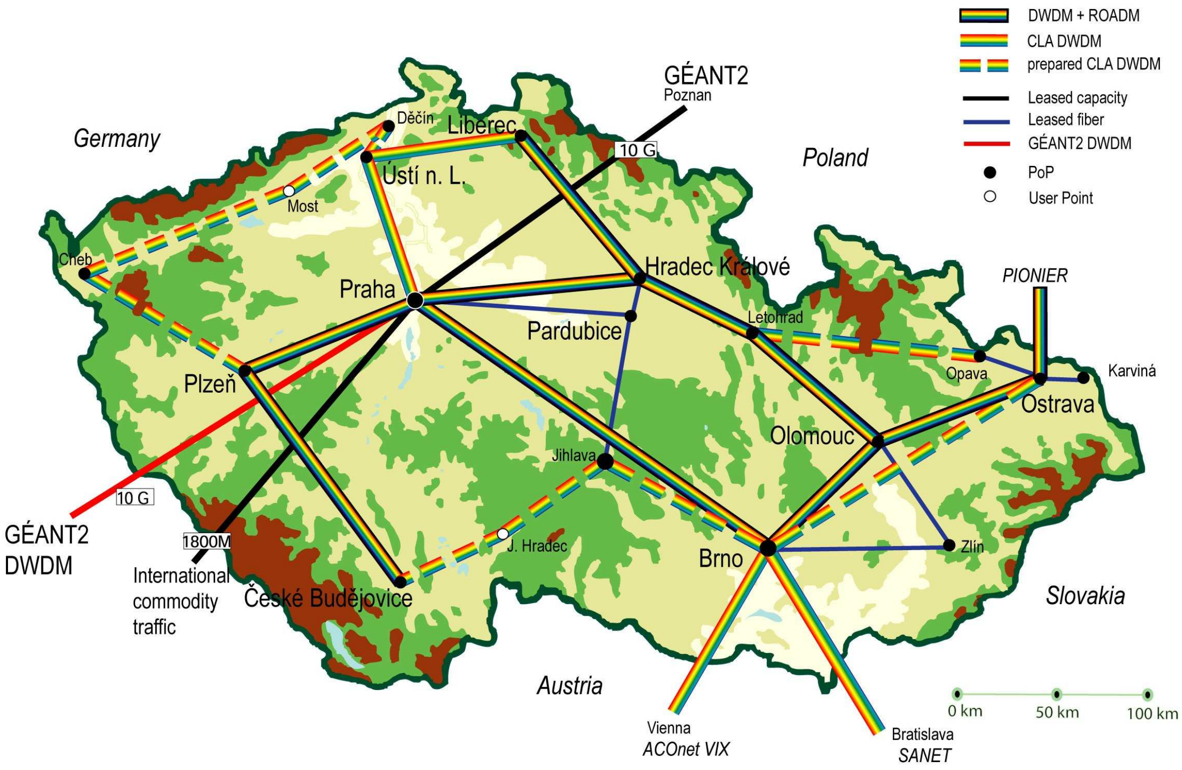

Figure 4.1: Mixed DWDM lighting in CESNET2 network and CBFs in June 2007

Deployment of photonic vendor equipment in networks with traditional vendors' equipment (interoperability)

Deployment of photonic vendor's products is not restricted to new dark fibre networks. CESNET proved in previous years that using open photonic devices and equipment of traditional vendors in one network (CESNET2) is possible and advantageous [13]. This was proved by CESNET also with SANET (190 km) and with ACOnet (224 km) for NIL CBFs. An example of such a solution is sometimes called "mixed lighting" is in Fig. 4.1

Another important recommendation for future NREN budgets comes from the comparison of lighting cost tables for single fibre transmission and fibre pair transmission, taking into account the cost of single fibre lease or ownership– see 5.3.

5 Fibre network cost model

5.1 Overall NREN budget per year

This chapter describes and discusses a fibre network cost model based on **annualized** overall network costs.

The most important task of NREN operation from economic point of view is **to overcome distances**.

A corresponding cost category in overall NREN budget is the **transmission cost** as a sum of

- Fibre cost
- Transmission equipment costs (fibre lighting costs).

If network is not fully based on dark fibres, we must include leased capacities on remaining routes into the transmission cost:

- Transmission capacity cost

Transmission costs in total are usually over 70% of network operation budget.

It is also constitutes over 70% of overall NREN budget, if no costs for research are planned (see paragraph below). This means transmission costs require special attention in economic analysis.

We have discussed transmission costs in detail in Chapters 3 and 4. The remaining cost categories in overall NREN budget in a suggested cost model are:

- PoP equipment costs,
- Other operational costs,
- Advanced research costs.

It will be discussed in this chapter. In opposition to transmission cost, the costs in this chapter are more difficult to estimate and compare in general - they depend more on time of equipment purchase, on using multi-vendor approach, the expected grows of network users and traffic, labour cost in a given country, intention of NREN to participate in research, etc. Fortunately, these issues are not crucial for budget proposal, supposing the estimation will be done with knowledge of usual values and relations and taking into account new results. For this purpose, examples are given in subchapters 5.2, 5.4 and Appendix B. In chapter 6, experts from beneficiary countries give their average estimations for their own countries for years 2007-2010, based on discussion with POS partners.

The calculation of annualized costs allows to compare the costs of different solutions and designs. We need to divide overall costs of items by supposed usage time and that is why the estimated usage time of equipment is one of the key input parameters. In general, use time can be different that the period used for calculation of depreciation (calculation of depreciation is driven by tax rules, diverging by needs in countries and times; moral and physical life time of fibres and equipment differ from their depreciation period). A partially similar situation occurs, when one-time setup costs are paid in fibre lease contracts for an indefinite period of time: use time of fibre need to be estimated for costs annualization. Fibre life span is usually longer than IRU contract period (IRU provider limits its own risk or fibre is not new at time of contracting, etc.).

By people without experience in accounting and economics annualized costs could be seen intuitively as the cost of resources used (consumed) in a given year. Front payment (non-recursive costs) requests of vendors are taken into account by calculation of time value (see 5.1.7) for long term acquirements (fibre construction, IRU). For short term acquirements (equipment) difference between value and time value in equipment purchase is not calculated in budgets, if supposed to be under inaccuracy of equipment cost and discounts estimation.

Item	Cost Category	Annualized costs (kE/y)	Percent	Note
1	*Transmission*			Fibre costs per year from table 5.2 plus lighting costs per year from table 5.3 plus capacity lease from table 5.4
2	*PoP Equipment*			PoP costs per year from table 5.5
3	*Other operational*			See table 5.6 for example
4	*Advanced research*			See subchapter 5.1.6
	TOTAL		100%	

Table 5.1: Table of Overall NREN budget

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The cost of fibre and transmission equipment are related mostly to distances. The cost of routing and switching equipment depends mostly on the number of NREN PoPs – see subchapters below. Calculating tables based on Excel sheets are available in Appendix A.

5.1.1 Annualized cost of fibre footprint

The biggest part of annual cost of NREN operation is usually the annualized cost of fibre acquiring. Decisions about fibre construction, IRU or lease have strong and long term impact on NREN economy. Fibre cost per meter and year in Euro is the main indicator of effectiveness of fibre acquiring. The usual values are between 0.1 and 1 E/m/y, depending on local conditions (see discussion in Chapter 3). Fibre footprint should consists of small ring(s) and preferred routes will be realized by implementing lambdas over this footprint.

PoP A	PoP B	Fibre length (km)	Usage time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
T o t a l							

Table 5.2: Fibre budget table

Annotations:

Usage time means the duration of usage expected by NREN, when the contract is signed for an indefinite period of time or when NREN will be owner, or duration is defined by contract, or when usage is limited by contract.

kE/y – kiloEUR/year

E/m/y – EUR/meter/year

Contract type – IRU, lease, single, pair, other

Fibre maintenance is included in fibre cost

PoP A	PoP B	Fibre length (km)	Usage time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
City G	City T	200	4	430	**108**	0,54	Lease pair
City G	City L	230	10	960	**96**	0,42	Lease pair
City G	City S	350	15	2900	**193**	0,55	IRU pair
City G	City U	125	4	230	**58**	0,46	Lease pair
City L	City T	125	4	270	**68**	0,54	Lease pair
City G	City S	250	4	510	**128**	0,51	Lease pair
Total		**1280**			**649**	**0,51**	

Table 5.2a: Example of fibre budget table

5.1.2 Annualized cost of lighting and transmission

The second biggest part of annual cost of NREN operation is usually the annualized cost of fibre lighting. Decisions about dependency on a single vendor of equipment or choosing on a multi-vendor solution, and also using advanced photonic lighting devices etc. (see Chapter 4) have strong impact on NREN's economy. Lighting cost per meter and year in Euro is the main indicator of effectiveness of fibre lighting. **The last column contains transmission cost** per year and meter as a sum of fibre cost per year and meter and lighting cost per year and meter. It is **the most important indicator of network effectiveness**, because transmission costs in total usually constitute over 70% of network operation budget.

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Usage time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m (E/m/y)	Tr. cost per m per y (E/m/y)
Total											

Table 5.3: Lighting and transmission budget table

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Annotations:

TE - Transmission Equipment

TE&M - TE and Maintenance (cost of maintenance can be about 10% of TE annualized cost)

IL COLO costs – Cost for collocation of In-Line transmission equipment, if not included in fibre acquiring costs (expected values are 1-5 kE/y per one in-line amplification site, see also [4])

Lighting cost = TE&M cost + IL COLO cost

Tr. cost (transmission cost) per year and meter = Lighting cost per year and meter + fibre cost per year and meter

Examples of lighting budget tables for alternative lighting scenarios are given in appendix B.

5.1.3 Transmission budget table for leased capacities

It is supposed that dark fibre will not be available for all lines, and especially in the first phase of Porta Optica development leased capacities for missing connections will be used temporarily. Budget for leased capacities will be added by Table 5.4. Since moving some transmission to dark fibres is supposed to take place in period between 2008 and 2010, new budget tables for a given NREN will be placed starting with the year of the supposed move (i.e. for the second or third phases of development), or step-wise changes will be described.

Depending on a local telecommunication market situation, the costs of leased capacities may be exceptionally lower than fibre acquiring based transmission. It is seldom true, if multiple GE or 10GE lambdas are needed. Transmission cost per meter and year (E/m/y) is an indicator used for comparison with the same indicator in Table 5.3.

PoP A	PoP B	Distance on road (km)	Usage time (year)	Transmission cost (kE)	Transmission cost per year (kE/y)	Transmission cost per meter and year (E/m/y)	Service type
Total							

Table 5.4: Transmission budget table for leased capacities

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Annotations:

Service types:

STM 1 or higher (or Sonet)

Ethernet (10M), Fast Ethernet (100M), GE, 10GE

lambda 1Gb/s, 2.5 Gb/s, 10 Gb/s or more, without framing etc.

If possible, the kind of service implemented on first mile(s) should be indicated too (e.g. fibre, microwave, or free space laser).

5.1.4 Annualized cost of equipment in PoPs

Annualized costs of equipment for PoPs depend on the type of service required. For beneficiary countries it should be taken into account, that network will be built and improved in dependence on fibre availability, technical preparation of users, financial support availability, etc. This means PoPs will be probably not heavy loaded and interfaced in the first few years. Depending life span of equipment, its replacement by new one and moving old items to new edge positions is possible, if necessary. Moreover, nowadays equipment costs keep falling down. There are advanced NRENs (for example SANET), where simple GE and 10GE switches in PoPs have been sufficient for a relatively long time and the supposed improvement trajectory is GE-10GE-100GE.

No vendor is supposed to be pre-selected or selected on the basis of budget proposals in this Deliverable. If some types of devices are mentioned (even for upgrading or extension of existing ones), it is strictly in the sense “this or a functionally equivalent device is planned”.

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Usage time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
Total								

Table 5.5: PoP equipment budget table

Annotations:

Type of PoP: common name for PoPs using the same equipment and having the same collocation conditions

R&SE - Routing and Switching Equipment including racks, energy backups, servers, workstations, PCs, testers, etc. for monitoring and maintenance

COLO cost: Total cost of collocation of PoPs of a given type. The collocation cost in universities consitutes usually about 5% of the annualized equipment cost

R&SE&M cost: R&SE annual costs plus maintenance cost (which usually consitutes about 10% of R&SE, but could be higher in case of solving problems of provider's network equipment faster)

Examples of cost equipment budget tables for alternative lighting scenarios are given in appendix B.

5.1.5 Other network operation costs

This subchapter should give an example of other costs needed to operate the network. These costs are significant and should not be left out.

Other operational costs do not depend directly on a transmission line or PoP equipment; they are mostly dependent on country-specific costs (for example labour cost).

In the following example there is a sum of 7895 kEUR as the total of network operation costs (items 1, 2 and 3 of Table 5.1). Item 3 represents the total Other network operation cost of 1395 kEUR for the network with about 5.000 km of dark fibre separated into 42 lines connecting 20 NREN PoPs. Person Month (PM) costs are about 2000 Euro/month. The fibre maintenance and in-line equipment annualized costs and collocation cost are included in item 1, as well as the equipment maintenance cost of about 430 kE/y and PoP equipment collocation costs of about 109 kE/y in item 2.

Item	Cost Category	Annualized costs (kE/y)	Percent	Note
3	***Other operation***	**1 395**	**17,67%**	
3.1	Material	40	-	
3.2	Labour	523	-	Technical labour costs plus outsourced permanent service costs (e.g. monitoring)
3.3	Travel	9	-	
3.4	Training	14	-	
3.5	Management and administration	730	-	Overhead relating to network operation (covering partly administrative services, top management, costs of using buildings, labs or offices etc.)

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3.6	Miscellaneous	79	-	Occasional services, SW (non-CAPEX) and other costs.
	TOTAL of Operation (1-3 items)	**7 895**	**100%**	Item 1,2 and 3 (Annualized cost of fibre plus annualized lighting costs plus annualized cost of routing and switching equipment, maintenance of equipment and collocation cost plus item 3)

Table 5.6: Example of Other Operational Cost in relation to annualized transmission cost and annualized PoP equipment cost.

Other operational costs could be very different in many NRENs, so budget estimation for each NREN in Chapter 6 should be done by analyzing differences in relation to the example above and the one in 5.2. If better estimation is not available, item 3 could be calculated as 20% of the sum of Item 1 and Item 2.

5.1.6 Research of advanced networking

Network operation costs analyzed above do not contain resources for improvement of networking. This means that an important aspect of NREN's general mission is not included in budget. Research networks are

- the most advanced part of the Internet,
- important source of Internet innovation,
- contributing to information technology innovation and deployment,
- contributing to economic prosperity.

Not all NRENs contribute to this world-wide mission. One of reasons could be that networking research is traditionally done at universities, research institutes or supercomputing centres in a given country. New NRENs and NRENs during their first stage of their evolution are usually targeted only at providing basic network services. It could be said, that top level research of networking is not necessary in each country (in contrary to the deployment of its results), but there are arguments against such a general rule:

- participation of more researchers form more countries brings new ideas and enhancement of results
- contribution of networking research to economic development and prosperity in a given country largely depends on participation of local researchers
- high quality of education depends on participation in top level research
- EU supports international research projects and participation of national resources is needed.

In the table below, one can see an example of what part of NREN's annual budget is used for research of networking and what part of staff workload is oriented at research of networking.

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	Research of networking	Network operation
% of total budget	42%	58%
% of total workload	73%	27%

Table 5.7: Relative budget for research of networking and network operation

The costs of equipment and fibre lease constitute a major part of the network operation budget. There is high synergy in doing network operation and research of networking in one subject (i.e. separation would be very expensive). Especially the development of a national research network is closely connected with research of networking. Nevertheless, outsourcing of routine tasks (for example non-stop monitoring) is usually successful.

We hope, that networking research in beneficiary countries will be increasing successfully and we look forward for future research cooperation with beneficiary countries' NRENs.

If better options are not available because of the lack of other sources of NREN's funding, we recommend to plan item 4 as 10% of the sum of Item 1 and Item 2 to keep track with world-wide networking research. It can be seen as a necessary condition for effective utilisation of NREN's budget as a whole.

For example, the involvement in research of networking (or more generally in research and development, R&D) could be seen in CESNET, GRNET, SURFNET, PSNC:

- More added value for the same costs:
  The results of the R&D allow to develop NREN's current services or implement new ones for the approximately the same level of costs for network providing. It means, the efficiency of the services including network providing is higher and more added value for the same costs is the effect for all users of the NREN services. The development of the services by means of purchases from suppliers would by more expensive.
- Better efficiency of the R&D
  The majority of employees working in R&D are part time staff. At the same time they are often employees of universities etc. Actually these NRENs have became organizations for cooperation of networking-oriented employees of universities and academies of sciences. This concentration of brains and sources, gives more efficiency and opportunities for all participants and investors. This is especially true for smaller countries.
- Contribution to an education system, telecommunication branch and economy
  This mission allows networking-oriented scientist to get involved in projects of international status and outcomes. The acquired know-how is brought to an education system and then, through the graduates, to business, which has positive effect on the telecommunication branch in general and it`s users. This business provides infrastructure for other branches, so it is possible to observe, that high-quality R&D brings contributions to the whole economy. High-quality R&D allows to reach the EU goals and to

increase technological level of EU members, and that is what the EU Research Framework or other national programs strongly promote.

5.1.7 Cost of front payment

The comparison of costs should distinguish between monthly payments and payments in advance (front payments), if we need to compare the annualized costs and then understand, which offers are more cost effective. If the installation fee, first mile building fee, purchase fee, One Time Charge (OTC) or Non-Recurring Charges (NRC) are used, then any of these fees should be divided by the usage time and the result should be added to one year cost. Any interest available should be also added, if the remaining part of NRC is used temporarily as a bank deposit (before using for Recurring Monthly Charges (RMC)). This means the time value of NRC instead of the value of NRC should be used in tables. (If repeated payments in advance are requested, you should evaluate the time value of each payment.)

Example of calculation is following:

Contract period (year)	Fibre acquiring cost (kE)	Usual interest on deposits	Expected deposit earnings (kE)	Time value of NRC (kE)	i.e. Fibre cost per year (kE/y)
10	42000	3%	7763	49763	4976
10	42000	6%	19057	61057	6106
10	42000	9%	35227	77227	7723
15	42000	3%	12872	54872	3658
15	42000	6%	35214	77214	5148
15	42000	9%	72903	114903	7660
20	42000	3%	19019	61019	3051
20	42000	6%	58171	100171	5009
20	42000	9%	135504	177504	8875

Table 5.8: Example of time value of NRC

Annotations:

Monthly interest method used.

Expected deposit earnings = Fibre acquiring cost * (1+ Usual interest on deposits/12)$^{\text{Use time in month}}$

– Fibre acquiring cost/Use time in month

*[(1+ Usual interest on deposits/12)$^{\text{Use time in month}}$ – 1]/ Usual interest on deposits/12

Time value of NRC = Expected deposit earnings + Fibre acquiring cost

Calculations for different input values can be done by double-click on this table. It can be seen, that even for small values of expected average interest the time value of NRC is used instead of the value of NRC, necessary for offers' comparison.

Table 5.8 is important also for comparison of equipment purchase/lease costs and for leasing of fibre and lighting equipment in one "lit fibre service" contract, developed by CESNET with some fibre providers. In contrary to capacity lease, with lit fibre service the whole capacity of fibre is dedicated to user.

An example of calculation, whether advance payment has advantages to a user, is as follows:

Contract period (year)	Advance payment offered (kE)	Alternative cost without adv. Pay. (kE)	i.e. monthly payment (kE)	Interest on deposits (p.a.)	Benefit of adv. pay. in comparison to monthly pay. (kE)
4	10000	10500	219	2%	90

Table 5.9: Example of cost comparison: advance payment vs. monthly payment

Annotations:

Monthly interest method used

Benefit of adv. pay = saving comes from adv. pay. plus interests on saving versus interest on temporary unpaid purchased cost (monthly pay.)

5.1.8 Initial payment

Initial payment indicates the payment needed to start transmission on a given link. In particular it is the cost of all needed equipment and fibers (in case of construction or purchase)

5.2 Budget for NREN operation using traditional vendors equipment

Traditional vendors of network equipment offer design kits including transmission systems, switches, routers and other components in one portfolio. The equipment should be able to interoperate. Network design should be based on this kit (sometimes these kits give more information about configuration than about the design).

Nearly all long-term working NRENs use routing and switching equipment from traditional vendors, because other possibilities are relatively new. PIONIER network will be used as a case study for the annualized cost analysis, because the data is publicly available. For simplicity, we do not separate costs per lines (no reasoning of budget request is needed for PSNC in this project), only cost sum of lines are presented.

PIONIER network consist of about 4418 km of its own or leased DF routes. All DWDM equipment used to carry two 10G lambdas was bought from one of the traditional vendors and installed on all DF routes, except for the lines where 1G transmission is leased. The switches bought from the same manufacturer are located in each PIONIER PoP. The two routers are localized in PSNC premises in Poznan. One of these routers plays a backup role. In order to have access to any network or power system devices, an “out-of-band” management system using GPRS / EDGE technology was installed in each PoP and amplifying node.

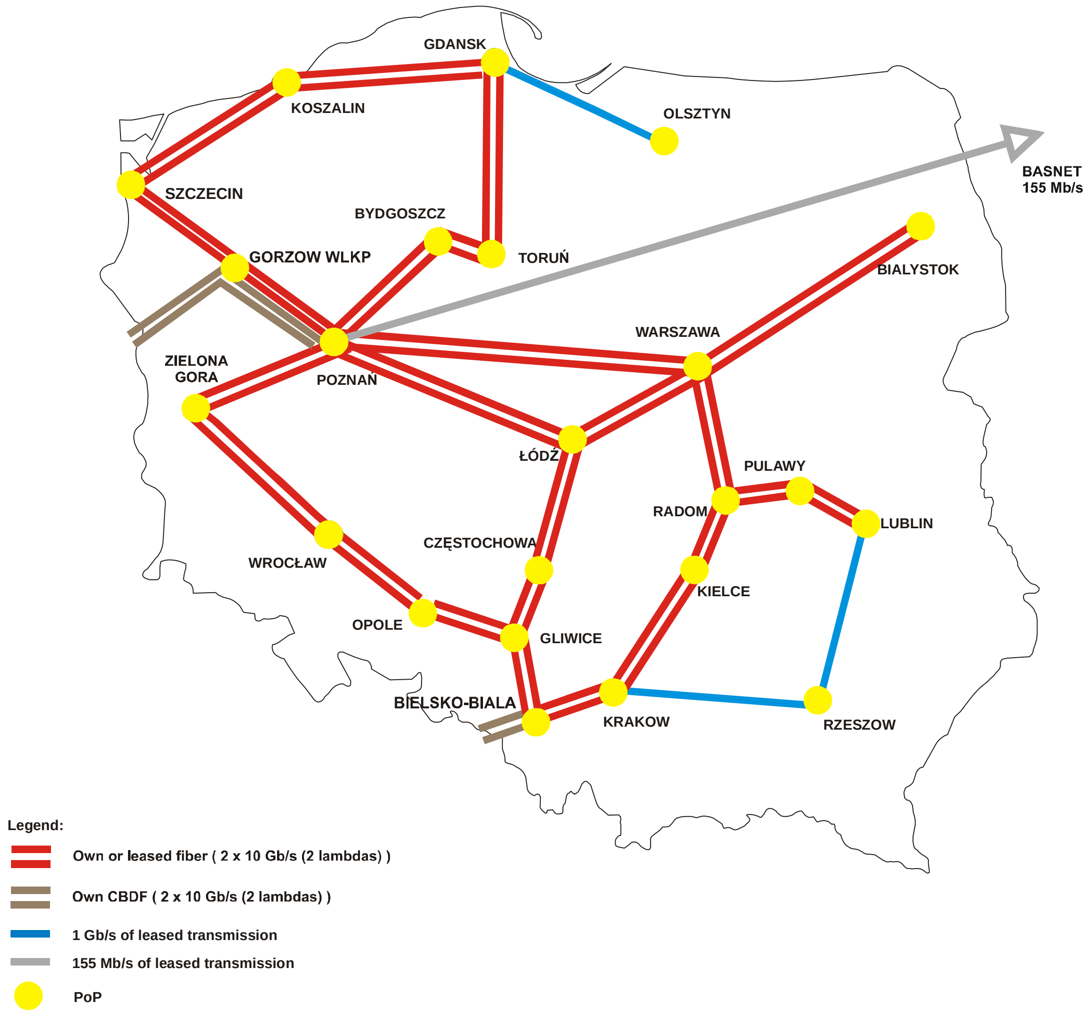

Figure 5.1: PIONIER network infrastructure in May 2007.

Fibre budget table

PIONIER fibre		Fibre length (km)	Use time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
all lines		4418	20	85999	4 299,95	0,97	Owning&M
					0,00	0,00	
					0,00	0,00	
T o t a l		**4418**			**4 299,95**	**0,97**	

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/y)	Percent
1	Transmission	6375,98	80,17
2	PoP Equipment	1061,16	13,34
3	Other operational	516,00	6,49
4	Advanced research		0,00
	TOTAL	7 953	100,00%

Lighting budget table

PIONIER Transmission Equip.		Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m (E/m/y)	Tr. cost per m per y (E/m/y)
all lines				5931	4	1 483	1 631		1 631,03	0,37	1,34
						0	0		0,00	0,00	0,00
						0	0		0,00	0,00	0,00
T o t a l		**0**	**0**			**1 483**	**1 631**	**0**	**1 631,03**	**0,37**	**1,34**

Transmission budget table for leased capacities

PIONIER capacities		Distance on road (km)	Contract period (year)	Transmission cost (kE)	Transmission cost per year (kE/y)	Transmission cost per meter and year (E/m/y)	Service type
all lines		482	4	1780	445,00	0,92	swap
					0,00	0,00	
					0,00	0,00	
T o t a l		**482**			**445,00**	**0,92**	

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
switch	24	110,33	2648	4	662,00	728,20	33,10	761,30
bord. router	2	521,50	1043	4	260,75	286,83	13,04	299,86
			0		0,00	0,00	0,00	0,00
T o t a l	**26**		**3691**		**922,75**	**1015,03**	**46,14**	**1061,16**

Table 5.10: Annualized costs of PIONIER network operation

Annotation:

- all prices quoted are gross prices
- 19019 kE added to have time value of front payment instead of value in fibre acquiring cost (20 years at 3% interest, see 5.1.7)
- Backbone router/switches (Foundry NetIron XMR 8000) installed last year in dozen of PoPs in Poland should satisfy the needs to upgrade services for network users' communities in connected metropolitan area networks (MAN) and to upgrade the backbone capacity. Each router/switch possesses two 10 GE ports with XFP in each direction (see Figure 5.1) and one module with twenty 1 GE ports for MAN purposes. More information about NetIron XMR 8000 is available on the website [28]. It could be taken

as an example for the future upgrade of networks in beneficiary countries, but prices are expected to go down in the future.

5.3 Cost effectiveness of single fibre transmission

Important recommendation for future networks could be derived from the comparison of lighting cost tables for single fibre transmission and fibre pair transmission, taking into account the cost of single fibre leasing or owning:

- if the cost of a single fibre line is lower than the cost of fibre pair (it depends on provider offers), it is necessary to compare the costs of both single and pair solutions (the annualized cost difference of fibres usually exceeds the annualized cost difference in lighting) – the annualized total cost difference can be about 40% and the transmission costs is usually the biggest item of NREN's budget
- NRENs owning or building fibres may decide about single fibre transmission, the remaining free fibres could be exchanged with other operators
- single fibre transmission is slightly more reliable than two fibre transmission (one fibre is sufficient for successful transmission whereas two fibres are necessary in fibre pair transmission).

From an optical point of view single fibre bidirectional transmission differs from fibre pair transmission in the presence of passive components, which split the transmission into two directions only. Thus the reliability of single fibre transmission devices is very similar to the fibre pair transmission devices. The number of providers offering single fibre lease is increasing. Typical cost of single fibre lease constitutes 60% of fibre pair lease, so it can be attractive for providers. NRENs building fibres are in an even better position. CESNET, for example, has not experience any problems with single fibre transmission since the beginning of deployment in 2003.

Traditional equipment vendor system designed for single fibre transmission also exists, for example Switzerland NREN SWITCH benefits from that system [19]. The method for cost-effective usage of fibre pair for single fibre transmission was developed in SWITCH: In one fibre long haul backbone traffic is carried bi-directionally in one fibre and the other fibre is used for aggregation of local tributaries.

Contracting for a single fibre footprint instead of a fibre pair footprint is expected to reduce the overall cost of the network significantly.

For example, we can calculate fibre budget tables and lighting budget tables for 200 km of fibre (single or pair) and for a 400 km line (single or pair) for some typical values (see Table 4.7 and Table 4.8).

PoP A	PoP B	Fibre length (km)	Usage time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
City A	City B	200	4	240	60	0.30	lease of single fibre
City A	City B	200	4	400	100	0.50	lease of fibre pair
City C	City D	400	4	480	120	0.30	lease of single fibre
City C	City D	400	4	800	200	0.50	lease of fibre pair

Table 5.11 Fibre budget table for single fibre and fibre pair – example

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Usag e time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m (E/m/y)	Tr. cost per m per y (E/m/y)
City A	City B	8	1	112.4	4	28.1	30.9	0.0	30.9	0.2	0.5
City A	City B	8	1	111.8	4	28.0	30.7	0.0	30.7	0.2	0.7
City C	City D	8	4	141.0	4	35.3	38.8	3.9	42.7	0.1	0.4
City C	City D	8	4	135.7	4	33.9	37.3	3.9	41.2	0.1	0.6

Table 5.12 Lighting budget table for single fibre and fibre pair - example

PoP A	PoP B	Fibre length (km)	Fibre cost per year (kE/y)	Lighting per year (kE/y)	Fibre + Lighting per year (kE/y)	Comparis on in percent	Contract type
City A	City B	200	60	30.9	90.9	100%	lease of single fibre
City A	City B	200	100	30.7	130.7	144%	lease of fibre pair
City C	City D	400	120	42.7	162.7	100%	lease of single fibre
City C	City D	400	200	41.2	241.2	148%	lease of fibre pair

Table 5.13 Comparison of transmission cost on single fibre and fibre pair - example

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Resulting cost difference in Table 4.9 is 44% respective 48% of transmission costs – a very good reason to study this issue and make appropriate decisions. We can repeat Nortel statement made in CEF Networks workshop 2005: “Where it is possible to get a single fibre, the deployment of the 2nd fibre is not likely to be cost effective or desirable” [25]. If some equipment vendor does not offer single fibre transmission, its lighting product portfolio should be seen as incomplete.

5.4 Cost of routing and switching equipment - open photonics design

In this subchapter we discuss the advantages of insisting on interoperability of devices and equipment of different vendors in procurement and contracting time. Interoperability and performance should be also confirmed by field testing. The equipment of photonics’ vendors (especially transceivers) as well as routers or switches of some traditional vendors are used.

It would be very difficult to give an exact price because possible configurations may vary extremely. Moreover, every purchase decision will be different because procurement rules are different in every country and the results will be influenced by other factors (negotiating skills, policy of a vendor in an area,...). On the other hand, mixed vendor approach is very cost effective, as experience indicates. It is definitely interesting for target countries.

Three different traditional vendors have been chosen to illustrate possible price differences. It is advisable that a modern Point of Presence (PoP) should offer 1 GE and even 10 GE interfaces to support the needs of research and educational communities and therefore all presented examples of routing/switching equipment support these features. It is important to keep in mind that even in these relatively simple examples, the real number of 1 GE and 10 GE ports may be different. In the examples, the number of 1 GE ports is approx. 8 – 16 and the number of 10 GE ports 2 – 4, which should be enough to satisfy all needs in the first phase of deployment. Many platforms can be configured as a level 3 (router) or a level 2 (switch) as needed. A legacy approach to classify the equipment into two basic categories – “expensive” core IP routers and “cheaper” Ethernet switches may be no longer valid. This new category of routing/switching equipment supports features like using pluggable optical transceivers (GBIC and SFP for 1 GE, XENPAK and XFP for 10 GE). These transceivers enable to choose the right type for every application (i.e. multimode or single mode fibres, for distances between a few metres and 80 kilometres without amplification). New DWDM versions of pluggable transceivers are available now, which allows for low cost DWDM transmission by using static DWDM multiplexers if dark fibres are available (more information can be found in figure [7] and in technical report [13]).

Some traditional vendors insist on using their so called “qualified transceivers” and in this case, the price of a few required DWDM pluggable transceivers may be higher than the price of the whole switch/router, as illustrated in Table 5.15. **It's very important to clarify this issue with every vendor very carefully in procurement. The acceptance of third party products should be included in the purchase contract.**

Another important criterion that has to be taken into account are maintenance and support fees and it has to be a part of procurement. The basic rule is 10% to 20% of the price of equipment (the more expensive equipment, the less maintenance fees).

As the final word it can be stressed that all numbers presented here are examples based on CESNET practical experience and it should be clear that other prices could be obtained as a result of procurement.

Type of equipment	Border router	Backbone router/switch	10 G switch	1 G switch
Price Vendor A	250 000 euro	50 000 euro	40 000 euro	8 000 euro
Price Vendor B	130 000 euro	42 000 euro	23 000 euro	6 000 euro
Price Vendor C	100 000 euro	23 000 euro	15 000 euro	3 000 euro

Table 5.14: Prices for different types of equipment

As may be seen from this table, the prices may vary really significantly and it will be useful to check the websites of NRENs to find more information which products are actually used and for what purposes.

It is not necessary to install these high-end routers/switches in every location. For example, the SURFnet6 network uses just four high-end routers together with Ethernet switching equipment and DWDM equipment (more details can be found in presentation [20]). In this scenario, every institution connected to SURFnet6 has its own routing equipment, which is not managed and therefore not paid by SURFnet.

The equipment listed in Table 5.14 belongs to similar technical categories although IPv6 (e.g. support of different routing protocols), Virtual Private LAN Services (VPLS) and other advanced features may differ. Which of these features are really needed - it is the question for experts from each beneficiary country. Tables 5.1 and 5.2 just try to illustrate possible economic results of a procurement process.

Any network will need a so called border router (or two for redundancy) which is capable of handling, for example, full Internet routing tables. The price of this border router will be significantly higher than typical prices from Tables 5.1 and 5.2. For example, PSNC has deployed two high end routers which cost 230 000 euros each. The reason for such a high price is that these routers are high end platforms with a big number of 10 G ports and they support most advanced features. Some re-estimation can be done and for a smaller number of 10 G ports, the price of a border router could be between 100 000 euros and 150 000 euros.

Yet it is not necessary to deploy such expensive equipment in all PoPs and for budgetary purposes the prices from Table 5.1 can be used for the rest of the network,. Vendor B can be chosen as a "middle course" example. The differences in prices may seem confusing, but one of the goals of Porta Optica Study is to find a budget allowing for a general solution, not a particular solution based on a proposal from a particular vendor.

A "middle course" example can be applied to all routing/switching equipment and prices for Vendor B from Table 5.14 may be chosen to make an examplary budget. The list of the equipment for one network is as follows: two border routers (130 000 euro), backbone router/switches (42 000 euro) are required for big PoPs and 1 G (6 000 euro) or 10 G (23 000 euro) switches are adequate for the rest of PoPs. If prices of equipment (which is to be deployed in a network) are known, they should be used instead of sample prices from Table 5.14.

A list of router/switch vendors (not exhaustive):

http://www.cisco.com/

http://www.juniper.net/

http://www.force10networks.com/

http://www.foundrynet.com/

http://www.extremenetworks.com/

http://www.nortel.com/

http://www.avici.com/

A list of pluggable transceivers vendors (not exhaustive):

http://www.opnext.com/

http://www.finisar.com/

http://www.bookham.com/

http://www.avanex.com/

http://www.optoway.com.tw/

http://www.ocp-inc.com/

In Appendix B a relatively simple but, on the other hand, rather vivid example of one network design is presented. It is thought that the design described in this Appendix can serve as an example to make the lighting issue understandable for readers without lighting design experience. It has to be to pointed out that an accurate project can be designed only with all accurate data (attenuation etc.) and thoughts and ideas presented in the following paragraphs and chapters are based on practical experiences obtained during the last few years in CESNET.

In addition to the price information from Table 5.14, the prices of other transmission equipment summarized in Table 5.15 are used for all budgetary calculations, for example in Appendix B. These prices are real numbers but it is important to mention they are results of ongoing negotiations of NRENs or any other organizations with manufacturers and suppliers (e.g. DWDM transceivers) and CESNET research activities (e.g. optical amplifiers, compensators). All prices are stated in euros.

Transceivers from photonics vendors	
GBIC/SFP (1 G, ZX 1550 nm)	500
GBIC/SFP (1G, DWDM)	1000
XENPAK/XFP (10 G, ZR 1550 nm)	3500
XENPAK/XFP (10 G, DWDM)	5000
Transceivers from traditional vendors	
GBIC/SFP (1 G, ZX 1550 nm)	3000
GBIC/SFP (1G, DWDM)	3000
XENPAK/XFP (10 G, ZR 1550 nm)	5500
XENPAK/XFP (10 G, DWDM)	11000
All other components from photonics vendors	
8 channel DWDM mux/demux (one pair)	3500
Optical add drop multiplexor (OADM)	2500
Dispersion compensating unit (fibre Bragg grating)	5000
Optical amplifier (booster)	12500
Optical amplifier (inline)	10000
Optical amplifier (preamp)	8000

Table 5.15: Prices of transmission components (EUR)

As can be seen from Table 5.15, the price difference of pluggable transceivers will vary significantly when buying directly from photonics vendors (called also manufacturers) as opposite to qualified optics from a traditional vendor. Moreover, sometimes it is possible to buy exactly the same transceiver from a manufacturer as is usually delivered by a traditional vendor (but price, etiquette and contract conditions differ).

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6 Budget recommended for NRENs in beneficiary countries

Each beneficiary country had a task to elaborate budget suggestions based on previous chapters, respective appendixes and on acquired information about fibre and service availability. The results have been unified as much as it was possible taking into account very different conditions. Consultation with CESNET, GRNET, PSNC or other partners was used very intensively by some beneficiary countries.

The budgets are based on prices quoted for NRENs by fibre or service providers, equipment vendors, etc.. Discounts were subtracted at a level, wich is usual for NRENs. If a value, row or table is missing in the budget tables for a given country (compared with Appendix A) it means, that for a given country it is not needed or that the value is zero. No budgetary reserve is added. The budgets are estimated based on today's knowledge.

Dark fibres are preferred in all cases, when available. Lighting is also considered in some beneficiary countries in traditional approach compared with open lighting approach. The transition from traditional lighting to open or mixed lighting should depend on the decisions of beneficiary NRENs. This means that financial support presented by the first budget table (traditional lighting) for each NREN in beneficiary countries is recommended and a NREN has opportunity to do extensions and improvements using open lighting. This means that the value of any item is not considered obligatory – the budget is obligatory only as a total sum.

Usually, a national government's (or funding agency) decision is as follows: **"We allocate X kEuro per year to support of a NREN. The NREN is responsible for the using the funds in the best way as recommended by POS project deliverables."** Similarly, multi-source funding should be conducting this way.

This approach allows the transition of NREN from capacity lease to dark fibre footprint and further to using of advanced lighting devices. In principle, all beneficiary countries expressed interest to go in this direction. Their experts in NRENs, universities and research institutes support this approach, but several local obstacles exist and the elaboration of detailed NRENs budget proposals is feasible for 2-3 years only. Also, it can be seen, that moving to advanced lighting is more important from an economic point of view for NRENs not using capacity lease (having transition to dark fibres ready).

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6.1 Estonia

The following network is planned to be implemented in the 1st phase:

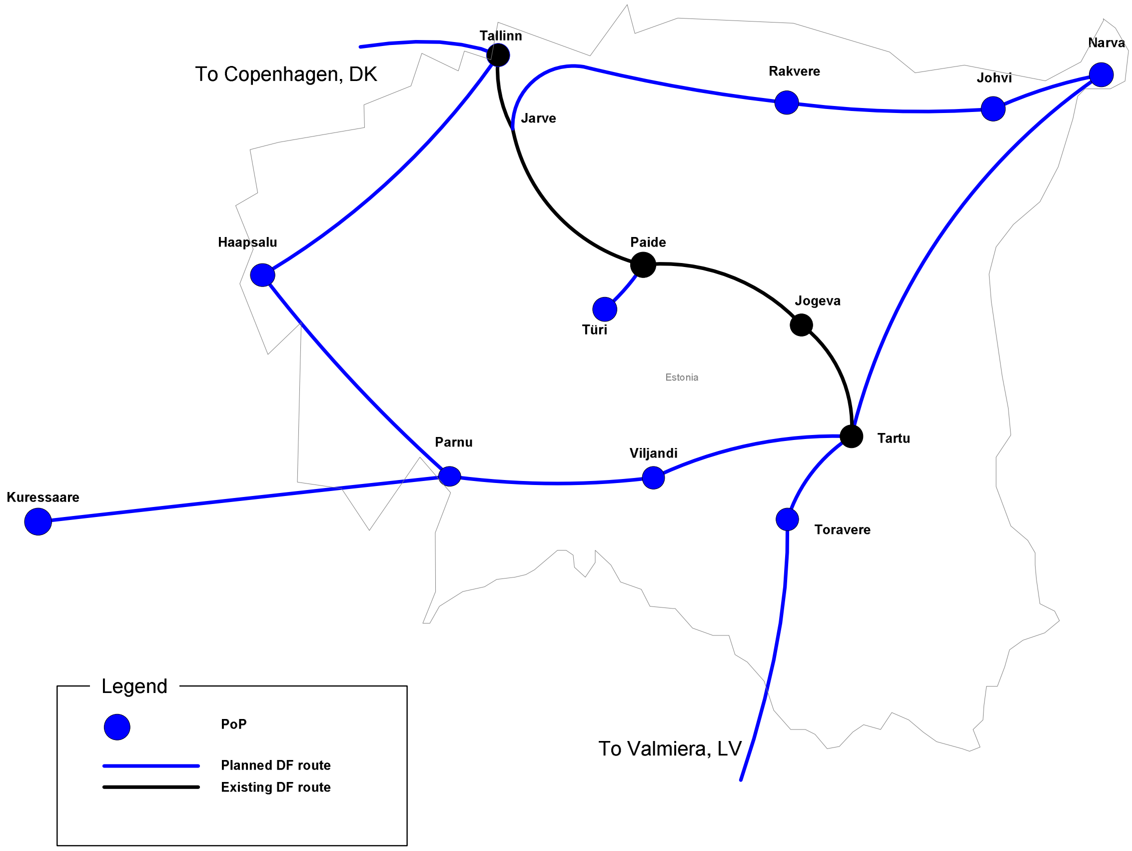

Figure 6.1 Estonian NREN existing and planned DF routes in the first phase.

Budget table 1: Dark fibre footprint, traditional lighting

Budget based on 'big vendors' devices for lighting equipment

Fibre budget table

PoP A	PoP B	Fibre length (km)	Use time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
Tallinn	Tartu	270	4	569	**142,25**	0,53	lease
Tallinn	Narva	250	4	527	**131,75**	0,53	lease
Tallinn	Haapsalu	100	4	211	**52,75**	0,53	lease
Tartu	Viljandi	80	4	169	**42,25**	0,53	lease
Viljandi	Pärnu	120	4	421	**105,25**	0,88	lease
Paide	Türi	15	4	32	**8,00**	0,53	lease
Tartu	Narva	200	4	421	**105,25**	0,53	lease
Haapsalu	Pärnu	125	4	263	**65,75**	0,53	lease
Pärnu	Kuressaare	150	4	316	**79,00**	0,53	lease
Tartu	Toravere	24	4	50	**12,50**	0,52	lease
Toravere	Valga	56	4	119	**29,75**	0,53	lease
Total		**1390**		**3098**	**774,50**		

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/y)	Percent
1	**Transmission**	**1143,04**	71,73
2	**PoP Equipment**	**82,80**	5,20
3	**Other operational**	**245,17**	15,38
4	**Advanced research**	122,58	7,69
	TOTAL 1-4	**1 593,60**	100,00

Lighting budget table

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m per y (E/m/y)	Tr. cost per m per y (E/m/y)
Tallinn	Tartu	3	4	446,4	5	89	98		**98,21**	0,36	
Tallinn	Narva	2	5	490,2	5	98	108		**107,84**	0,43	
Tallinn	Haapsalu	1	2	19,2	5	4	4		**4,22**	0,04	
Tartu	Viljandi	2	1	120	5	24	26		**26,40**	0,33	
Viljandi	Pärnu	1	1	33,6	5	7	7		**7,39**	0,06	
Paide	Türi	1	1	12	5	2	3		**2,64**	0,18	
Tartu	Narva	1	3	73,8	5	15	16		**16,24**	0,08	
Haapsalu	Pärnu	1	2	38,4	5	8	8		**8,45**	0,07	
Pärnu	Kuressaare	1	2	66,6	5	13	15		**14,65**	0,10	
Tartu	Toravere	3	1	163,2	5	33	36		**35,90**	1,50	
Toravere	Valga	2	1	211,8	5	42	47		**46,60**	0,83	
Total		**18**	**23**	**1675,20**		**335,04**	**368,54**	**0,00**	**368,54**		

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
Border	2	130	260	5	52,00	57,20	2,60	**59,80**
10 G capable	2	23	46	5	9,20	10,12	0,46	**10,58**
1 G capable	9	6	54	5	10,80	11,88	0,54	**12,42**
Total	**13**		**360,00**		**72,00**	**79,20**	**3,60**	**82,80**

Initial payment necessary to start transmission on recommended links is **2 035 200 €**. It includes the cost of the equipment (both PoP and lighting equipment).

Overall NREN budget needed for successful network development in Estonia using traditional lighting is: **1 593 600 €** per year

6.2 Latvia

The following network is planned to be implemented in the 1st phase:

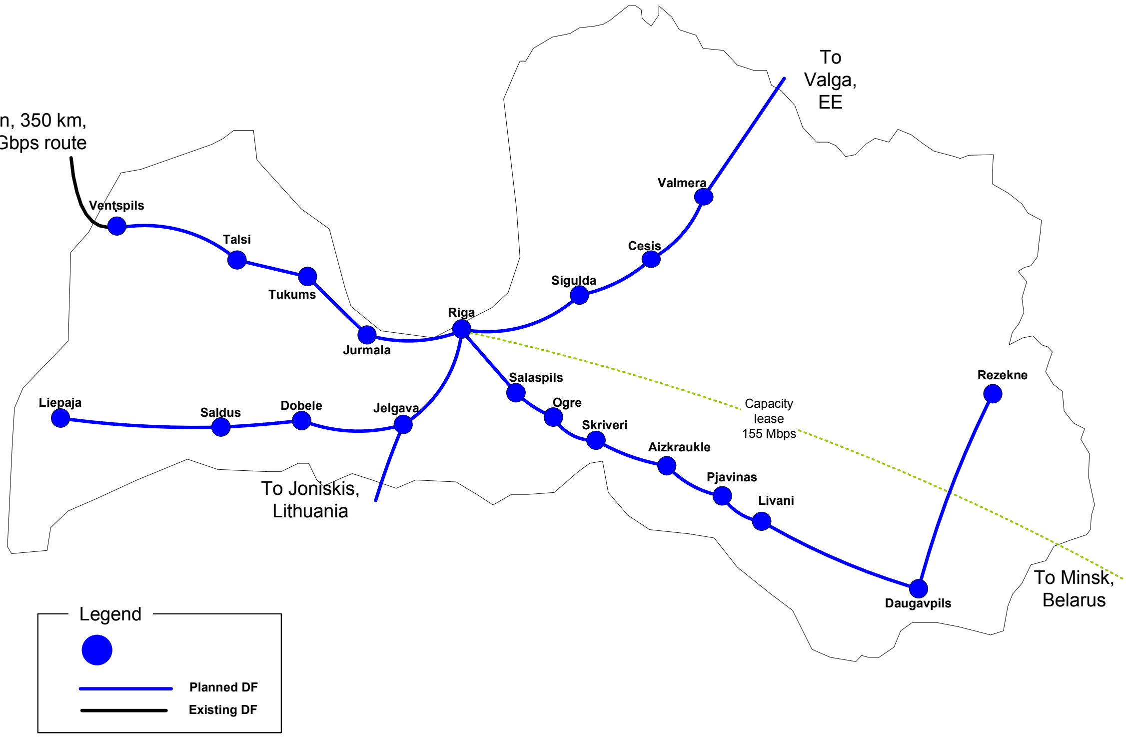

Figure 6.2. Phase 1 of fibre network development in Latvia

Budget table 1: Dark fibre footprint, traditional lighting

Fibre budget table

PoP A	PoP B	Fibre length (km)	Contract period (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per kilometer and year (E/m/y)	Contract type
Riga	Daugavpils	230	3	910,8	**303,60**	1,32	lease
Daugavp.	Rezekne	130	3	514,8	**171,60**	1,32	lease
Riga	Jelgava	50	3	198	**66,00**	1,32	lease
Jelgava	Liepaja	180	3	712,8	**237,60**	1,32	lease
Riga	Ventspils	200	3	792	**264,00**	1,32	lease
Riga	Valka	205	3	811,8	**270,60**	1,32	lease
Jelgava	Joniškis	40	15	3600	**240,00**	6,00	purchase
T o t a l		**1035**		**7 540,20**	**1 553,40**		

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/y)	Percent
1	**Transmission**	**2006,56**	72,91
2	**PoP equipment**	**110,40**	4,01
3	**Other operational**	**423,39**	15,38
4	**Advanced research**	**211,70**	7,69
	TOTAL	**2 752,05**	

Lighting budget table

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m (E/m/y)	Tr. cost per m per y (E/m/y)
Riga	Daugavpils	2	7	612	5	122	135	0	**135**	0,59	1,91
Daugavp.	Rezekne	1	1	39	5	8	9	0	**9**	0,07	1,39
Riga	Jelgava -Joniskis	3	2	265	5	53	58	0	**58**	0,65	1,97
Jelgava	Liepaja	1	3	114	5	23	25	0	**25**	0,14	1,46
Riga	Ventspils	2	4	610	5	122	134	0	**134**	0,67	1,99
Riga	Valka	4	4	421	5	84	93	0	**93**	0,45	1,77
T o t a l		**13**	**21**	**2 060**		**411,96**	**453,16**	**0,00**	**453,16**		

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
Border router	2	130	260	5	52,00	57,20	2,60	**59,80**
Backbone R/S	2	42	84	5	16,80	18,48	0,84	**19,32**
10G	2	23	46	5	9,20	10,12	0,46	**10,58**
1G	15	6	90	5	18,00	19,80	0,90	**20,70**
T o t a l	**21**		**480**		**96,00**	**105,60**	**4,80**	**110,40**

Initial payment necessary to start transmission on recommended links is **6 140 000 €**. It includes the cost of the equipment (both PoP and lighting equipment) and the cost of fibre on Jelgava – Joniskis route.

Overall NREN budget needed for successful network development in Latvia using traditional lighting is: **2 752 050 € per year**

Budget table 2: Dark fibre footprint, photonic lighting

Fibre budget table

PoP A	PoP B	Fibre length (km)	Use time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
Riga	Daugavpi	230	3	910,8	**304**	1,32	lease
Daugavp.	Rezekne	130	3	514,8	**172**	1,32	lease
Riga	Jelgava	50	3	198	**66**	1,32	lease
Jelgava	Liepaja	180	3	712,8	**238**	1,32	lease
Riga	Ventspils	200	3	792	**264**	1,32	lease
Riga	Valka	205	3	811,8	**271**	1,32	lease
Jelgava	Joniškis	40	15	3600	**240**	6,00	purchase
Total		**1035**		**7 540**	**1 553**		

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/y)	Percent
1	**Transmission**	**1676,38**	69,22
2	**PoP Equipment**	**110,40**	4,56
3	**Other operational**	**423,39**	17,48
4	**Advanced research**	211,70	8,74
	TOTAL	**2421,87**	**100,00%**

Lighting budget table

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m per y (E/m/y)	Tr. cost per m per y (E/m/y)
Riga	Daugavpi	2	7	119	3	40	44	0,00	**44**	0,19	1,51
Daugavp.	Rezekne	1	1	9	3	3	3	0,00	**3**	0,03	1,35
Riga	Jelgava	2	1	17	3	6	6	0,00	**6**	0,12	1,44
Jelgava	Liepaja	1	3	51	3	17	19	0,00	**19**	0,10	1,42
Riga	Ventspils	2	4	68	3	23	25	0,00	**25**	0,12	1,44
Riga	Valka	2	4	68	3	23	25	0,00	**25**	0,12	1,44
Jelgava	Joniškis	1	1	17	15	1	1	0,00	**1**	0,03	6,03
Total		**11**	**21**	**349**		**112**	**123**	**0**	**123**		

Transmission budget table for leased capacities

PoP A	PoP B	Distance on road (km)	Contract period (year)	Transmission cost (kE)	Transmission cost per year (kE/y)	Transmission cost per meter and year (E/m/y)	Service type
Total		**0**			**0,00**	**0,00**	

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
Border	2	130	260	5	52,00	57,20	2,60	**59,80**
Backbone	2	42	84	5	16,80	18,48	0,84	**19,32**
10G capa	2	23	46	5	9,20	10,12	0,46	**10,58**
1G capab	15	6	90	5	18,00	19,80	0,90	**20,70**
Total	**21**		**480**		**96,00**	**105,60**	**4,80**	**110,40**

Initial payment necessary to start transmission on recommended links is **4 429 000 €**. It includes the cost of the equipment (both PoP and lighting equipment) and the cost of fibre on Jelgava – Joniskis route.

Overall NREN budget needed for successful network development in Latvia using photonic lighting is: **2 421 870 € per year**

6.3 Lithuania

The following network is planned to be implemented in the 1st phase:

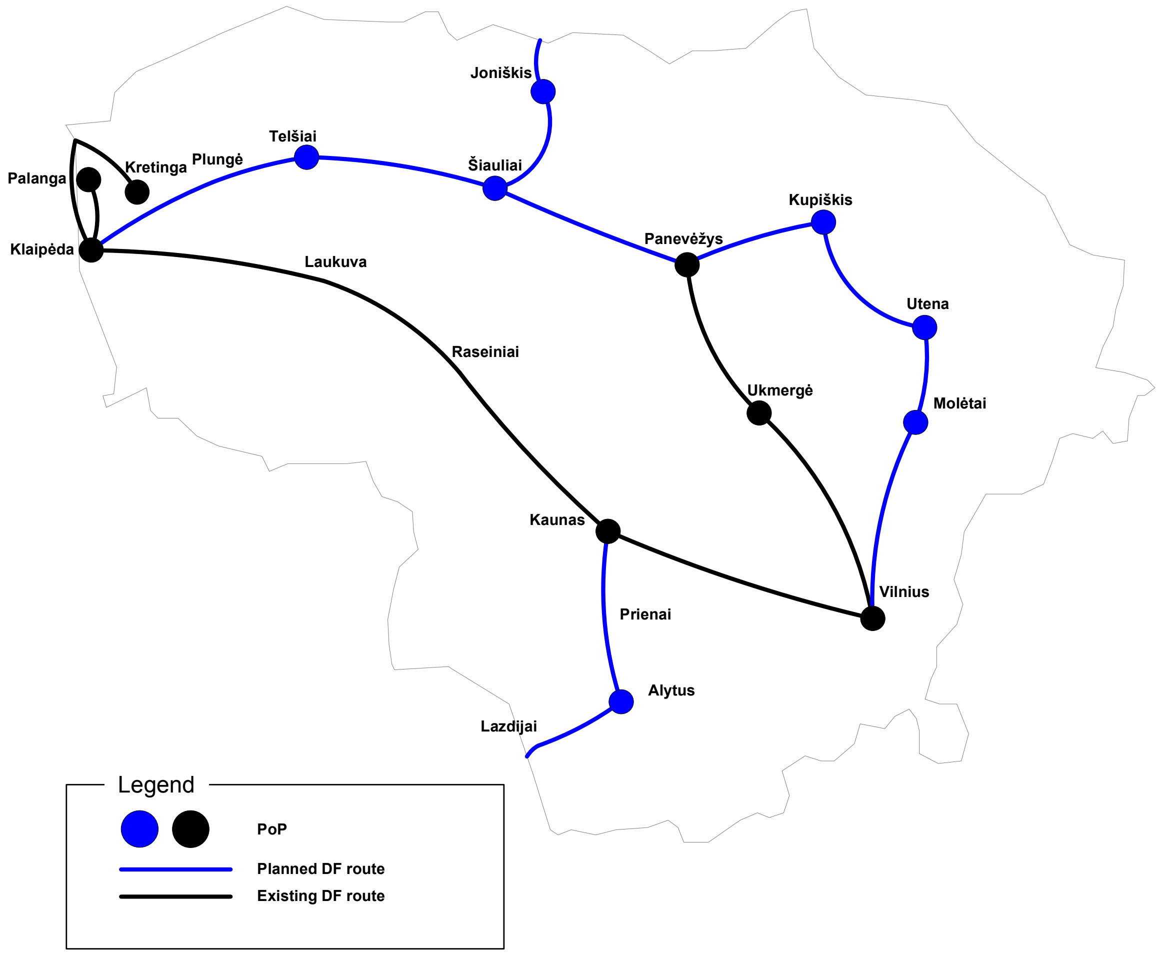

Figure 6.3. Lithuanian NREN existing and planned DF routes in the first phase.

Budget table 1: Dark fibre footprint, traditional lighting

PoPA	PoPB	Fibre length (km)	Use time (year)	Fibre acquiring cost (k€)	Fibre cost per year (k€/y)	Fibre cost per meter and year (€/m/y)	Contract type
KTU	KU	240					acquired
VU	KTUPI	144					acquired
KTU	MI	124					WDM in operation
KU	SU	150	20	674,66	33,73	0,22	purchase
SU	KTUPI	70	20	314,84	15,74	0,22	purchase
KTU	Lazdijai	138	3	289,86	96,62	0,70	lease
SU	Joniškis	41	3	86,12	28,71	0,70	lease
KTUPI	VU	252	4	312,14	78,03	0,31	lease
Total		651		1677,61	252,83		

Item	Cost Category	Annualized costs (k€/y)	Percent
1	Transmission	689,21	64,75
2	PoP Equipment	129,61	12,18
3	Other operational	163,76	15,38
4	Advanced research	81,88	7,69
	TOTAL	1064,46	100,00%

Lighting budget table

PoPA	PoPB	Number of lambdas	Number of spans	TE costs (k€)	Use time (year)	TE costs per year (k€/y)	TE&M costs per year (k€/y)	ILCOLO cost (k€/y)	Lighting per year (k€/y)	Lighting per m per y (€/m/y)	Tr. cost per m per y (€/m/y)
KTU	KU	3	3	264	4	66	73	6	78,60	0,33	0,33
VU	KTUPI	4	2	318	4	80	87	0	87,45	0,61	0,61
KTU	MI	7	1	30	4	8	8	0	8,25	0,07	0,07
KU	SU	4	5	336	5	67	74	0	73,92	0,49	0,72
SU	KTUPI	3	2	174	5	35	38	0	38,28	0,55	0,77
KTU	Lazdijai	3	3	324	5	65	71	3	74,28	0,54	1,24
SU	Joniškis	3	1	210	5	42	46	3	49,20	1,20	1,90
KTUPI	VU	3	4	120	5	24	26	0	26,40	0,10	0,41
Total		30	21	1776		386	424	12	436,38		

Transmission budget table for leased capacities

PoPA	PoPB	Distance on road (km)	Contract period (year)	Transmission cost (k€)	Transmission cost per year (k€/y)	Transmission cost per meter and year (€/m/y)	Service type
					0,00	0,00	
Total		0			0,00	0,00	

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (k€)	R&SE cost (k€)	Use time (year)	R&SE cost per year (k€/y)	R&SE&M cost (k€/y)	COLO cost (k€/y)	PoP cost per year (k€/y)
10G core	5	150	750	10	75,00	82,50	3,75	86,25
10G acce	1	23	23	10	2,30	2,53	0,12	2,65
10G back	3	100	300	10	30,00	33,00	1,50	34,50
1G acces	9	6	54	10	5,40	5,94	0,27	6,21
Total	18		1127		112,70	123,97	5,64	129,61

Initial payment necessary to start transmission on recommended links is **3 892 500 €**. It includes the cost of the equipment (both PoP and lighting equipment) and the cost of fibre purchase on some routes.

Overall NREN budget needed for successful network development in Lithuania using traditional lighting is: **1 064 460 € per year**

Budget table 2: Dark fibre footprint, photonic lighting

Fibre budget table

PoP A	PoP B	Fibre length (km)	Use time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
KTU	KU	240					acquired
VU	KTUPI	144					acquired
KTU	MII	124					WDM in operation
KU	SU	150	20	674,66	**33,73**	0,22	purchase
SU	KTUPI	70	20	314,84	**15,74**	0,22	purchase
KTU	Lazdijai	138	3	289,86	**96,62**	0,70	lease
SU	Joniškis	41	3	86,12	**28,71**	0,70	lease
KTUPI	VU	252	4	312,14	**78,03**	0,31	lease
Total		**651**		**1677,61**	**252,83**		

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/y)	Percent
1	Transmission	**379,84**	50,30
2	PoP Equipment	**129,61**	17,16
3	Other operational	**163,76**	21,69
4	Advanced research	81,88	10,84
	TOTAL	755,08	100,00%

Lighting budget table

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m per y (E/m/y)	Tr. cost per m per y (E/m/y)
KTU	KU	3	3	91	4	23	25	6	**31,03**	0,13	0,13
VU	KTUPI	4	2	64	4	16	18	0	**17,60**	0,12	0,12
KTU	MII	7	1	30	4	8	8	0	**8,25**	0,07	0,07
KU	SU	4	5	73,5	5	15	16	0	**16,17**	0,11	0,33
SU	KTUPI	3	2	34,5	5	7	8	0	**7,59**	0,11	0,33
KTU	Lazdijai	3	3	66,5	5	13	15	3	**17,63**	0,13	0,83
SU	Joniškis	3	1	56,5	5	11	12	3	**15,43**	0,38	1,08
KTUPI	VU	3	4	60,5	5	12	13	0	**13,31**	0,05	0,36
Total		**30**	**21**	**476,5**		**105**	**115**	**12**	**127,01**		

Transmission budget table for leased capacities

PoP A	PoP B	Distance on road (km)	Contract period (year)	Transmission cost (kE)	Transmission cost per year (kE/y)	Transmission cost per meter and year (E/m/y)	Service type
Total		**0**			**0,00**	**0,00**	

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
10G core	5	150	750	10	75,00	82,50	3,75	**86,25**
10G acce	1	23	23	10	2,30	2,53	0,12	**2,65**
1G core	3	100	300	10	30,00	33,00	1,50	**34,50**
1G acces	9	6	54	10	5,40	5,94	0,27	**6,21**
Total	**18**		**1127**		**112,70**	**123,97**	**5,64**	**129,61**

Initial payment necessary to start transmission on recommended links is **2 591 000 €**. It includes the cost of the equipment (both PoP and lighting equipment) and the cost of fibre purchase on some routes.

Overall NREN budget needed for successful network development in Lithuania using photonic lighting is: **755 080 € per year.**

6.4 Belarus

The following network is planned to be implemented in the 1st phase:

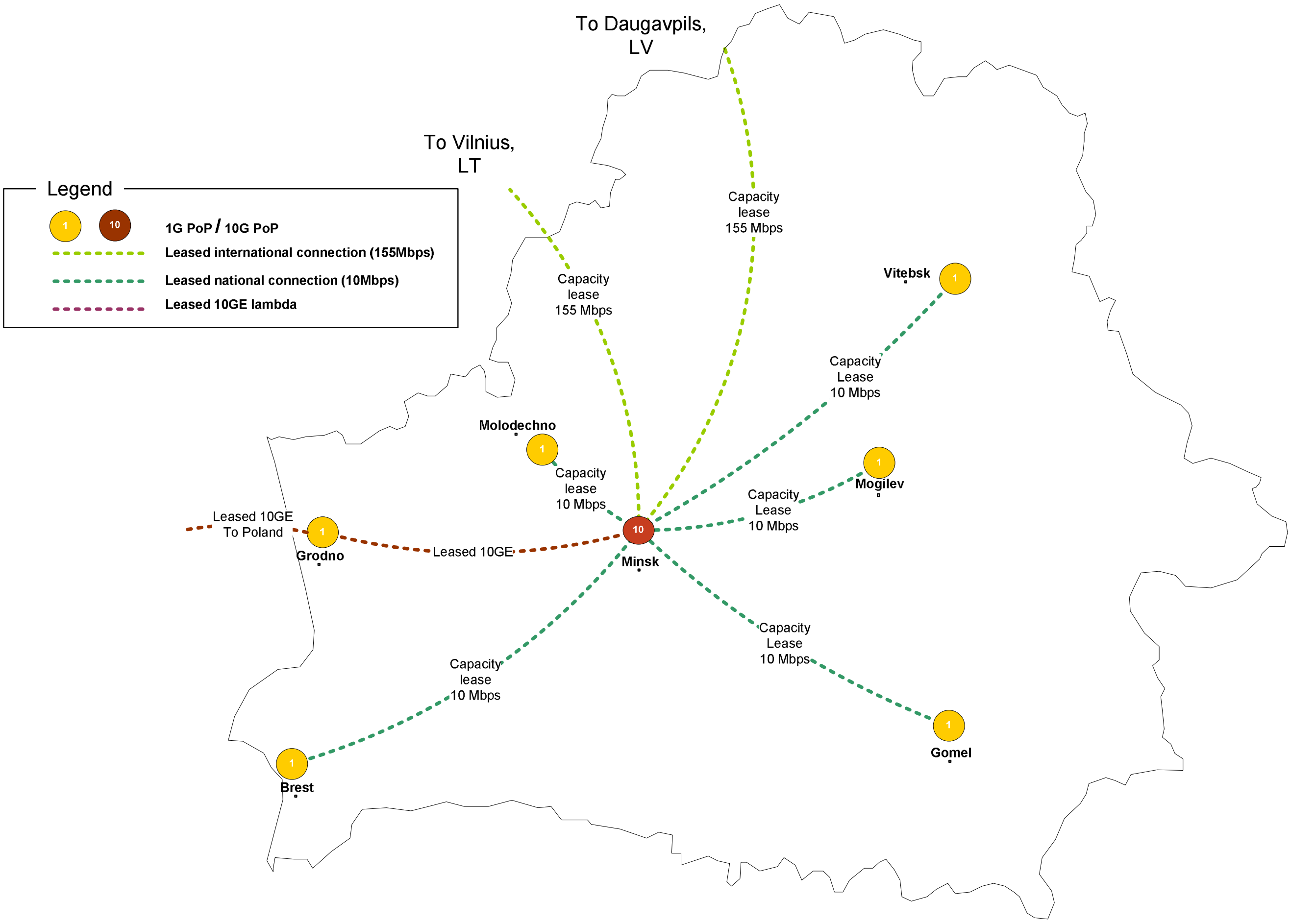

Figure 6.4. First phase of Belarusian research and education network development.

Budget table 1: First step to dark fibre footprint, traditional lighting

Fibre budget table

PoP A	PoP B	Fibre length (km)	Use time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
Minsk	Minsk 1	10	4	35	8,75	0,88	owned
Minsk 1	Minsk2	10	4	35	8,75	0,88	owned
Minsk 2	Minsk 3	10	4	35	8,75	0,88	owned
Minsk 3	Minsk4	15	4	52,5	13,13	0,88	owned
Total		45		157,5	39,38		

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/y)	Percent
1	Transmission	1 712,00	85,08
2	PoP Equipment	150,15	7,46
3	Other operational	50,00	2,48
4	Advanced research	100,00	4,97
	TOTAL	2 012,15	100,00%

Lighting budget table 10 G

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m per y (E/m/y)	Tr. cost per m per y (E/m/y)
Minsk	Grodno	1	4	500	4	125	144	14	158,13	0,59	2,45
Total		1	4			125	144	14	158,13		

Transmission budget table for leased capacities

PoP A	PoP B	Distance on road (km)	Contract period (year)	Transmission cost (kE)	Transmission cost per year (kE/y)	Transmission cost per meter and year (E/m/y)	Service type
Minsk	Grodno	269	4	2 000	500	1,86	leased 10 Gbps
Minsk	Vitebsk	269	4	226	57	0,21	leased 10 Mbps
Minsk	Brest	345	4	226	57	0,16	leased 10 Mbps
Minsk	Gomel	302	4	226	57	0,19	leased 10 Mbps
Minsk	Mogilev	204	4	226	57	0,28	leased 10 Mbps
Minsk	Maladzechn	76	4	226	57	0,74	leased 10 Mbps
Minsk	Riga	500	4	1 344	336	0,67	leased STM-1
Grodno	Kuznica Bialostocka	15	4	240	60	4,00	leased 10GB
Minsk	Vilnius	190	4	1 344	336	1,77	leased STM-1
Total		2170		6 058	1 515		

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
R&SE	11	30	330	4	82,50	90,75	0,00	90,75
Border	1	216	216	4	54,00	59,40	0,00	59,40
Total	12		546		136,50	150,15	0,00	150,15

Initial payment necessary to start transmission on recommended links is **1 204 000 €**. It includes the cost of the equipment (both PoP and lighting equipment) and the cost of fiber purchase in Minsk.

Overall NREN budget needed for successful network development in Belarus is: **2 012 150 €** per year.

6.5 Ukraine

The following network is planned to be implemented in the 1st phase:

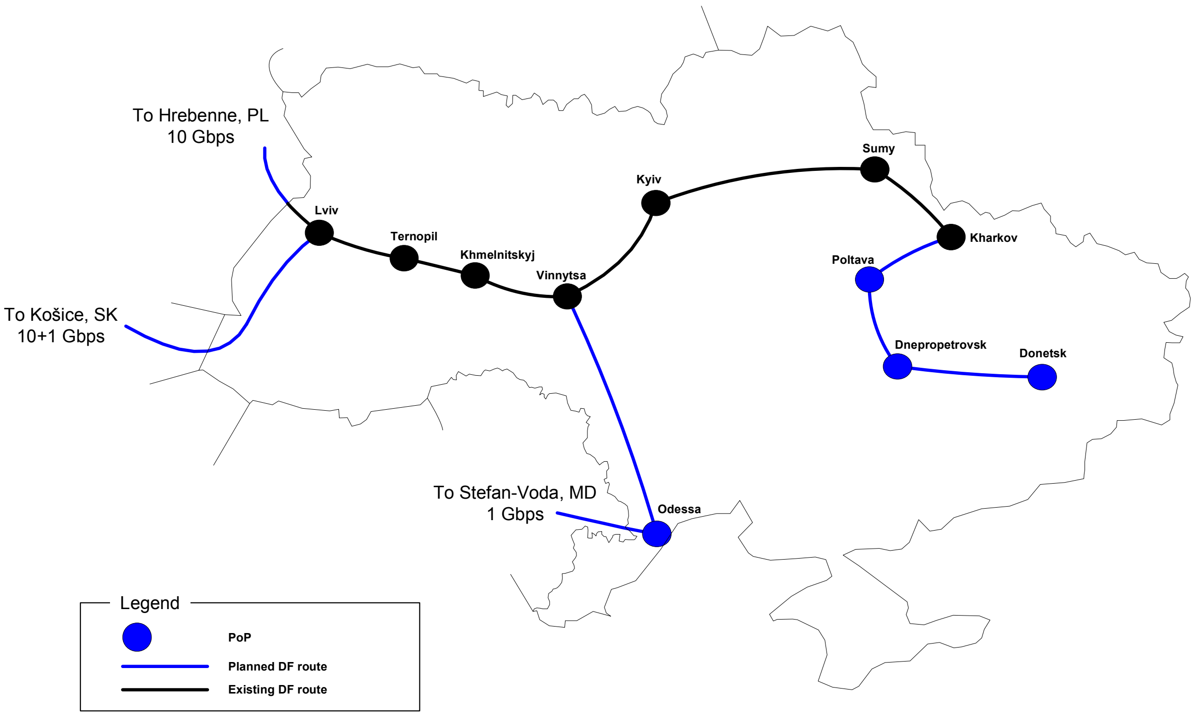

Figure 6.5. Ukrainian NREN existing and planned DF routes in the first phase

Budget table 1: Dark fibre footprint, traditional lighting

Fibre budget table

PoP A	PoP B	Fibre length (km)	Use time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
Lviv	Vinnytsa	445	4	514	**128,50**	0,29	lease
Vinnytsa	Kyiv	260	4	301	**75,25**	0,29	lease
Livv	Hrebenne	80	4	96	**24,00**	0,30	lease
Lviv	Uzhgorod	324	4	387	**96,75**	0,30	lease
Kyiv	Donetsk	1227	4	1506	**376,50**	0,31	lease
Vinnitsa	Odessa	455	4	546	**136,50**	0,30	lease
Odessa	Stefan-Voda	110	20	605	**30,25**	0,28	construct
Total		**2901**		**3 955,00**	**867,75**		

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/y)	Percent
1	Transmission	**1809,97**	73,22
2	PoP Equipment	**91,54**	3,70
3	Other operational	**380,30**	15,38
4	Advanced research	**190,15**	7,69
	TOTAL 1-4	**2 471,96**	100,00

Lighting budget table

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m per y (E/m/y)	Tr. cost per m per y (E/m/y)
Lviv	Vinnytsa	5	9	1042,80	5	208,56	229,42		**229,42**	0,52	0,80
Vinnytsa	Kyiv	6	4	591,00	5	118,20	130,02		**130,02**	0,50	0,79
Livv	Hrebenne	2	1	178,80	5	35,76	39,34		**39,34**	0,49	0,79
Lviv	Uzhgorod	2	4	367,20	5	73,44	80,78		**80,78**	0,25	0,55
Kyiv	Donetsk	1	15	1212,60	5	242,52	266,77		**266,77**	0,22	0,52
Vinnitsa	Odessa	2	6	480,60	5	96,12	105,73		**105,73**	0,23	0,53
Odessa	Stefan-Voda	1	2	48,00	5	9,60	10,56		**10,56**	0,10	0,37
Total		**19**	**41**	**3921,00**		**784,20**	**862,62**	**0**	**862,62**		

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
Border	1	130	130	5	26,00	28,60	1,30	**29,90**
Backbone	2	42	84	5	16,80	18,48	0,84	**19,32**
10 G capable	8	23	184	5	36,80	40,48	1,84	**42,32**
Total	**11**		**398**		**79,6**	**87,56**	**3,98**	**91,54**

Initial payment necessary to start transmission on recommended links is **4 924 000 €**. It includes the cost of the equipment (both PoP and lighting equipment) and the cost of fibre construction.

Overall NREN budget needed for successful network development in Ukraine using traditional lighting is: **2 471 960 € per year**

6.6 Moldova

The following network is planned to be implemented in the 1st phase:

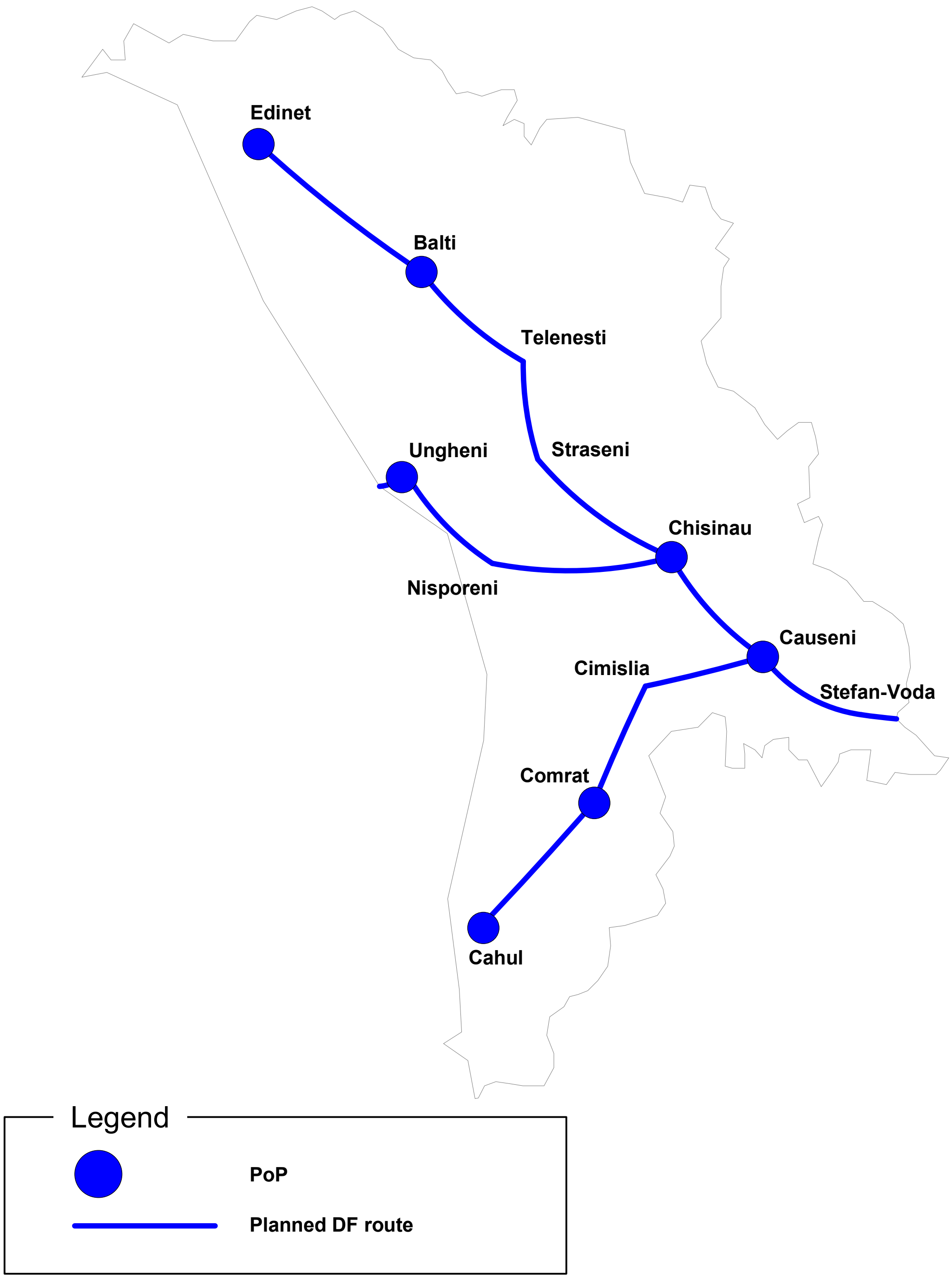

Figure 6.6. Moldavian NRENs DF routes planned in the first phase

Project: Porta Optica Study
Deliverable Number: D3.2v3
Date of Issue: 24/10/07
EC Contract No.: 026617
Document Code: POS-15-001v3

Budget table 1: Dark fibre footprint, traditional lighting

PoP A	PoP B	Fibre length (km)	Use time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
Chisinau	Ungheni	133	20	771,5	**38,58**	0,29	construction
Chisinau	Balti	158	5	584,6	**116,92**	0,74	lease pair
Balti	Edinet	84	5	322,4	**64,48**	0,77	lease pair
Chisinau	Causeni	90	5	344	**68,80**	0,76	lease pair
Causeni	Stefan-Vo	50	5	200	**40,00**	0,80	lease pair
Causeni	Comrat	96	5	365,6	**73,12**	0,76	lease pair
Comrat	Cahul	85	5	326	**65,20**	0,77	lease pair
Total		**696**		**2 914,10**	**467,10**		

Item	Cost Category	Annualized costs (kE/y)	Percent
1	Transmission	**544,50**	73,04
2	PoP Equipment	**28,98**	3,89
3	Other operational	**114,70**	15,38
4	Advanced research	57,35	7,69
	TOTAL	**745,52**	**100,00%**

Lighting budget table

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m per y (E/m/y)	Tr. cost per m per y (E/m/y)
Chisinau	Ungheni	2	2	75	5	15	17	6	**22,50**	0,17	0,46
Chisinau	Edinet	1	4	90	5	18	20	6	**25,80**	0,11	0,86
Chisinau	Stefan-Vo	2	3	102	5	20	22	3	**25,44**	0,18	0,96
Causeni	Cahul	1	3	3	5	1	1	3	**3,66**	0,02	0,78
Total		**6**	**12**	**270**		**54**	**59**	**18**	**77,40**		

Transmission budget table for leased capacities

PoP A	PoP B	Distance on road (km)	Contract period (year)	Transmission cost (kE)	Transmission cost per year (kE/y)	Transmission cost per meter and year (E/m/y)	Service type
					0,00	0,00	
Total		**0**			**0,00**	**0,00**	

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
border	2	42	84	5	16,80	18,48	0,84	**19,32**
1G core	7	6	42	5	8,40	9,24	0,42	**9,66**
Total	**9**		**126**		**25,20**	**27,72**	**1,26**	**28,98**

Initial payment necessary to start transmission on recommended links is **1 167 500 €**. It includes the cost of the equipment (both PoP and lighting equipment) and the cost of fibre construction.

Overall NREN budget needed for successful network development in Moldova using traditional lighting is: **745 520 € per year**

Project: Porta Optica Study
Deliverable Number: D3.2v3
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Document Code: POS-15-001v3

Budget table 2: Dark fibre footprint, photonic lighting

Fibre budget table

PoP A	PoP B	Fibre length (km)	Use time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
Chisinau	Ungheni	133	20	771,5	38,58	0,29	construction
Chisinau	Balti	158	5	584,6	116,92	0,74	lease pair
Balti	Edinet	84	5	322,4	64,48	0,77	lease pair
Chisinau	Causeni	90	5	344	68,80	0,76	lease pair
Causeni	Stefan-Vo	50	5	200	40,00	0,80	lease pair
Causeni	Comrat	96	5	365,6	73,12	0,76	lease pair
Comrat	Cahul	85	5	326	65,20	0,77	lease pair
Total		696			467,10		

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/y)	Percent
1	Transmission	501,82	71,40
2	PoP Equipment	28,98	4,12
3	Other operational	114,70	16,32
4	Advanced research	57,35	8,16
	TOTAL	702,85	100,00%

Lighting budget table

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m per y (E/m/y)	Tr. cost per m per y (E/m/y)
Chisinau	Ungheni	2	2	17,8	5	4	4	6	9,92	0,07	0,36
Chisinau	Edinet	1	4	20,2	5	4	4	6	10,44	0,04	0,80
Chisinau	Stefan-Vo	2	3	35,8	5	7	8	3	10,88	0,08	0,86
Causeni	Cahul	1	3	2,2	5	0	0	3	3,48	0,02	0,78
Total		6	12	76		15	17	18	34,72		

Transmission budget table for leased capacities

PoP A	PoP B	Distance on road (km)	Contract period (year)	Transmission cost (kE)	Transmission cost per year (kE/y)	Transmission cost per meter and year (E/m/y)	Service type
					0,00	0,00	
Total		0			0,00	0,00	

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
border	2	42	84	5	16,80	18,48	0,84	19,32
1G core	7	6	42	5	8,40	9,24	0,42	9,66
Total	9		126		25,20	27,72	1,26	28,98

Initial payment necessary to start transmission on recommended links is **973 500 €**. It includes the cost of the equipment (both PoP and lighting equipment) and the cost of fibre construction.

Overall NREN budget needed for successful network development in Moldova using photonic lighting is: **702 850 € per year.**

6.7 Georgia

The following network is planned to be implemented in the 1st phase:

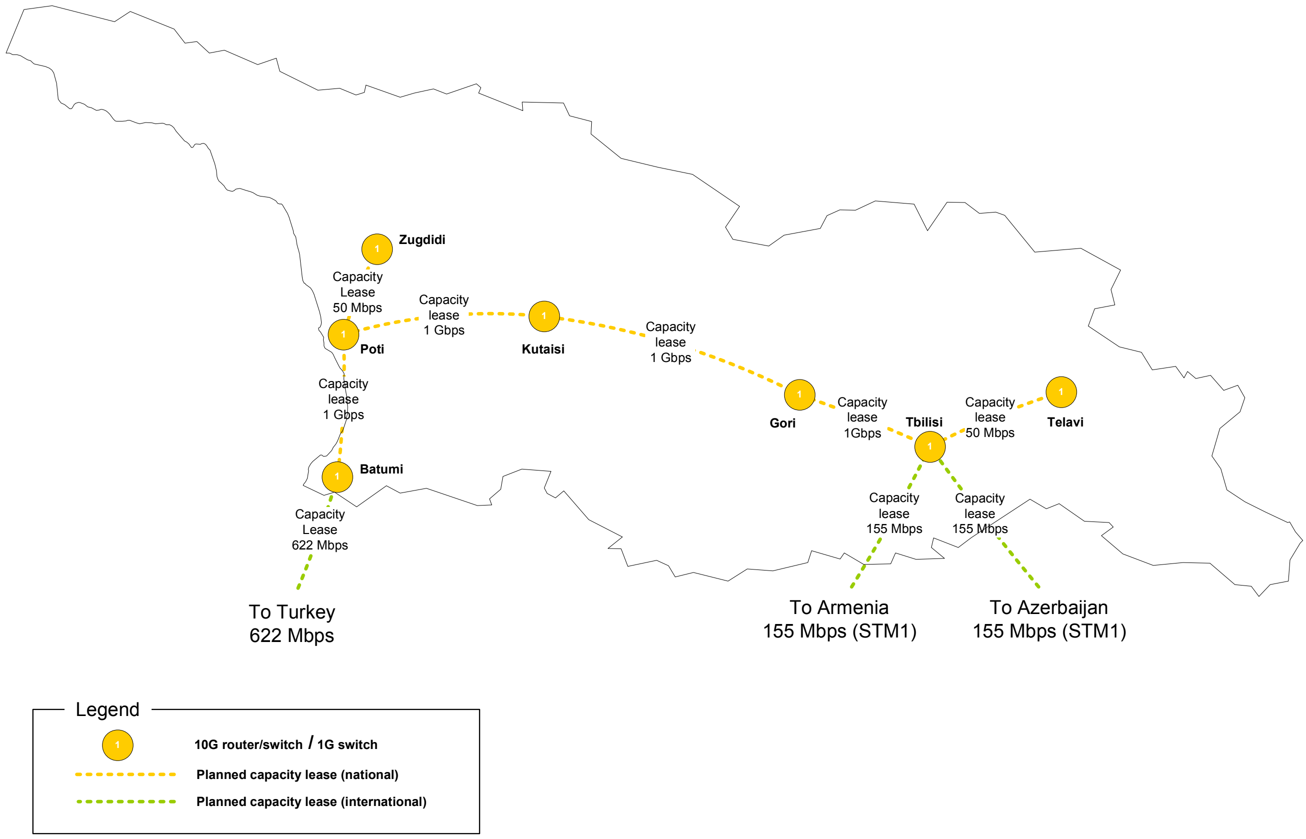

Figure 6.7. Georgian NREN's leased transmission capacity in the first phase.

Budget table 1: Leased capacities

Fibre budget table

PoP A	PoP B	Fibre length (km)	Use time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
No DF available							
Total		0			0,00	0,00	

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/y)	Percent
1	Transmission	1955,17	90,53
2	PoP Equipment	40,48	1,87
3	Other operational	98,40	4,56
4	Advanced research	65,60	3,04
	TOTAL 1-4	2 159,65	100,00

Lighting budget table - photonics vendors

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m per y (E/m/y)	Tr. cost per m per y (E/m/y)
No DF available, no lighting equipment is needed											
Total		0	0			0	0	0	0	0	

Transmission budget table for leased capacities

PoP A	PoP B	Distance on road (km)	Contract period (year)	Transmission cost (kE)	Transmission cost per year (kE/y)	Transmission cost per meter and year (E/m/y)	Service type
Batumi	Istanbul (Turkey)	1500	1	1734	1 734,00	1,16	STM4
Tbilisi	Gori	71	3	50,5	16,83	0,24	1GE
Gori	Kutaisi	142	3	101	33,67	0,24	1GE
Kutaisi	Poti	92	3	65	21,67	0,24	1GE
Poti	Batumi	201	3	143	47,67	0,24	1GE
Poti	Zugdidi	115	3	144	48,00	0,42	50Mbps
Tbilisi	Telavi	167	3	160	53,33	0,32	50Mbps
Total		2288		2 397,50	1 955,17		

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
Border	2	40	80	5	16,00	17,60	0,80	18,40
Backbone	4	20	80	5	16,00	17,60	0,80	18,40
10 G capable	2	8	16	5	3,20	3,52	0,16	3,68
Total	8		176		35,20	38,72	1,76	40,48

Initial payment necessary to start transmission on recommended links is **176 000 €**. It is the cost of the PoP equipment.

Overall NREN budget needed for successful network development in Georgia using leased capacity connections is: **2 159 650 €** per year

6.8 Armenia

The following network is planned to be implemented in the 1st phase:

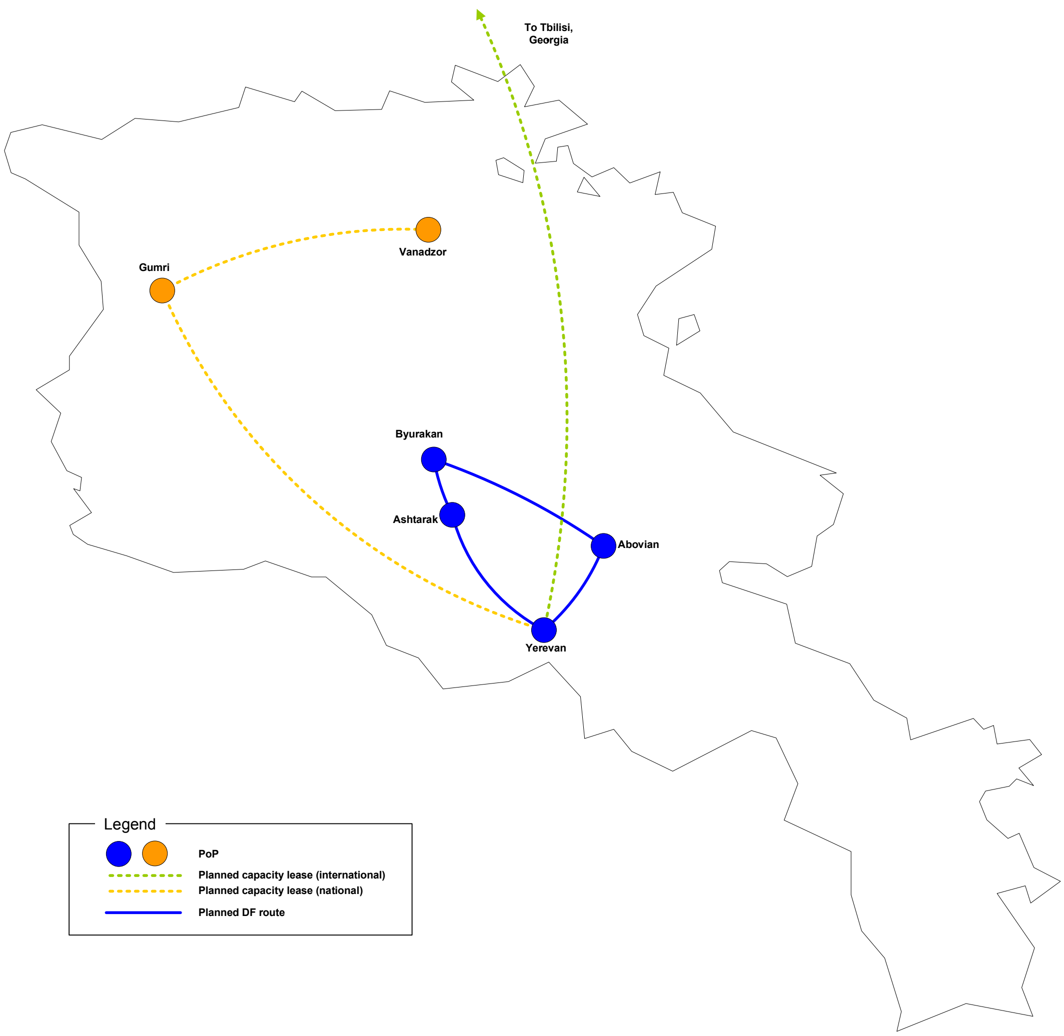

Figure 6.8: Phase 1 of fiber network development in Armenia

Budget table 1: Dark fibre footprint, traditional lighting

Fibre budget table - construction

PoP A	PoP B	Fibre length (km)	Use time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
YER	ASH	41	20	310	15,50	0,38	construct
ASH	BYUR	15	20	120	6,00	0,40	construct
BYUR	AB	88	20	670	33,50	0,38	construct
AB	YER	33	20	250	12,50	0,38	construct
Total		177		1350	67,50		

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/y)	Percent
1	Transmission	3210,36	94,78
2	PoP equipment	32,66	0,96
3	Other operational	94,00	2,78
4	Advanced research	50,00	1,48
TOTAL		3387,02	100

Lighting budget table - traditional vendors

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m per y (E/m/y)	Tr. cost per m per y (E/m/y)
YER	ASH	1	1	32,8	5	6,56	7,22	0	7,22	0,18	0,55
ASH	BYUR	1	1	32,8	5	6,56	7,22	0	7,22	0,48	0,88
BYUR	AB	1	1	32,8	5	6,56	7,22	0	7,22	0,08	0,46
AB	YER	1	1	32,8	5	6,56	7,22	0	7,22	0,22	0,60
Total		4	4	131,2		26,24	28,86	0,00	28,86		

Transmission budget table for leased capacities

PoP A	PoP B	Distance on road (km)	Contract period (year)	Transmission cost (kE)	Transmission cost per year (kE/y)	Transmission cost per meter and year (E/m/y)	Service type
YER	VAN	245	3	900	300	1,22	STM-1
IST (Turkey)	BATUMI (Georgia)	1500	1	1734	1734	1,16	STM-4 (shared)
YER	TBL	345	1	1080	1080	3,13	STM-1
Total		2090		3714	3114		

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
border	1	42	42	5	8,40	9,24	0,42	9,66
backbone	5	20	100	5	20,00	22,00	1,00	23,00
Total	6		142		28,40	31,24	1,42	32,66

Initial payment necessary to start transmission on recommended links is **1 623 200 €**. It includes the cost of the equipment (both PoP and lighting equipment) and the cost of fibre links construction.

Overall NREN budget needed for successful network development in Armenia using traditional lighting is: **3 387 020 € per year**

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Budget table 2: Dark fibre footprint, photonic lighting

Fibre budget table - construction

PoP A	PoP B	Fibre length (km)	Use time (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
YER	ASH	41	20	310	15,50	0,38	construct
ASH	BYUR	15	20	120	6,00	0,40	construct
BYUR	AB	88	20	670	33,50	0,38	construct
AB	YER	33	20	250	12,50	0,38	construct
Total		177		1350	67,50		

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/y)	Percent
1	Transmission	3182,60	94,74
2	PoP Equipment	32,66	0,97
3	Other operational	94,00	2,80
4	Advanced research	50,00	1,49
TOTAL		3359,26	100

Lighting budget table

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m per y (E/m/y)	Tr. cost per m per y (E/m/y)
YER	ASH	1	1	1	4	0,25	0,28	0	0,28	0,01	0,38
ASH	BYUR	1	1	1	4	0,25	0,28	0	0,28	0,02	0,42
BYUR	AB	1	1	1	4	0,25	0,28	0	0,28	0,00	0,38
AB	YER	1	1	1	4	0,25	0,28	0	0,28	0,01	0,39
Total		4	4	4		1,00	1,10	0,00	1,10		

Transmission budget table for leased capacities

PoP A	PoP B	Distance on road (km)	Contract period (year)	Transmission cost (kE)	Transmission cost per year (kE/y)	Transmission cost per meter and year (E/m/y)	Service type
YER	VAN	245	3	900	300	1,22	STM-1
IST (Turkey)	BATUMI (Georgia)	1500	1	1734	1734	1,16	STM-4 (shared)
YER	TBL	345	3	3240	1080	3,13	STM-1
Total		2090		5874	3114		

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
border	1	42	42	5	8,40	9,24	0,42	9,66
backbone	5	20	100	5	20,00	22,00	1,00	23,00
Total	6		142		28,40	31,24	1,42	32,66

Initial payment necessary to start transmission on recommended links is **1 496 000 €**. It includes the cost of the equipment (both PoP and lighting equipment) and the cost of fibre links construction.

Overall NREN budget needed for successful network development in Armenia using photonic lighting is: **3 359 260 €** per year

6.9 Azerbaijan

The following network is planned to be implemented in the 1st phase:

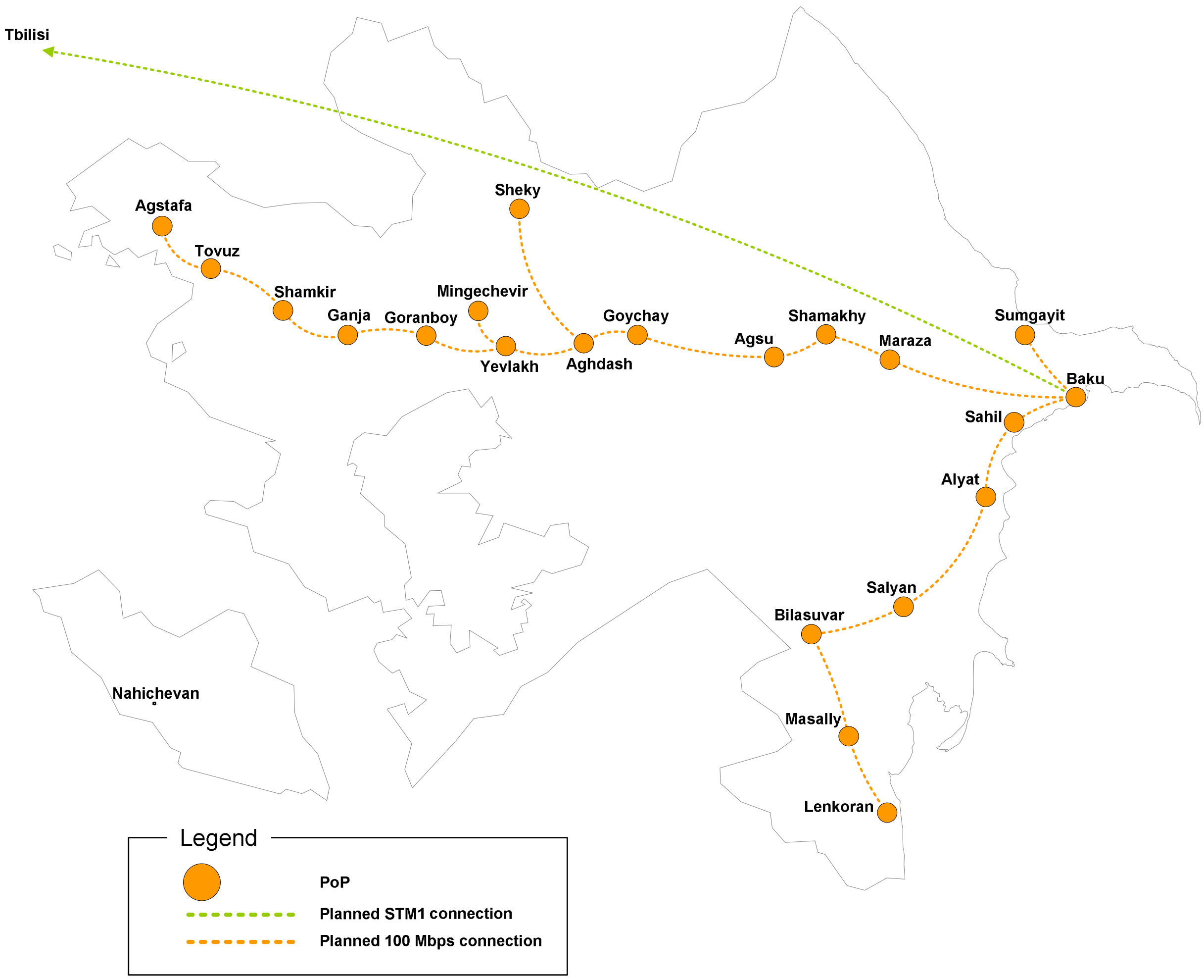

Figure 6.9. Azerbaijani NREN's leased transmission capacity in the first phase.

Budget table 1: International leased connection + national support

Fibre budget table

PoP A	PoP B	Fibre length (km)	Contract period (year)	Fibre acquiring cost (kE)	Fibre cost per year (kE/y)	Fibre cost per meter and year (E/m/y)	Contract type
No DF available							
Total		0			0,00	0,00	

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/y)	Percent
1	Transmission	3390,00	88,39
2	PoP Equipment	35,42	0,92
3	Other operational	246,00	6,41
4	Advanced research	164,00	4,28
	TOTAL	3835,42	100,00%

Lighting budget table

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m (E/m/y)	Tr. cost per m per y (E/m/y)
No DF available, no lighting equipment is needed											
Total		0	0			0	0	0	0,00	0,00	0,00

Transmission budget table for leased capacities

PoP A	PoP B	Distance on road (km)	Contract period (year)	Transmission cost (kE)	Transmission cost per year (kE/y)	Transmission cost per meter and year (E/m/y)	Service type
Baku	Tbilisi	610	1	1656	1 656,00	2,71	STM-1
Istanbul (Turkey)	Batumi (Georgia)	1500	1	1734	1 734,00	1,16	STM-4 (shared)
Total		2110		3 390,00	3 390,00		

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
R&SE	19	114	5	22,80	25,08	1,14	26,22
Border	1	40	5	8,00	8,80	0,40	9,20
Total	20	154		30,80	33,88	1,54	35,42

Annotation:

- the permission to use national infrastructure is received as government support

Initial payment necessary to start transmission on recommended links is **154 000 €.** It includes the cost of the equipment (both PoP and lighting equipment) and the cost of fibre links construction.

Overall NREN budget needed for successful network development in Azerbaijan using leased capacity connections is: **3 835 420 €** per year.

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7 Conclusion

The most important recommendations for the governments and NRENs of target countries, GN2 and European Commission are:

A. Governments of Armenia, Azerbaijan, Belarus, Estonia, Georgia, Latvia, Lithuania, Moldova and Ukraine should recognise Research networks as a crucial element of equal participation in world-wide research.The governments should undertake appropriate steps to support the NRENs by giving the guarantees of an access to the national fiber infrastructure and proper funding of the NRENs from the state budget starting from 2008. Such a decision will also stimulate building the Information Society in beneficiary countries and **improve overall country prosperity** (see [27]).

B. Porta Optica Study beneficiary NRENs should support building new optical cables and metropolitan fibre structures based on expert knowledge. Comprehensive collaboration between NRENs, especially in dark fiber network development, is necessary to gain access to the state of the art knowledge and experience in networking.

C. GN2 and GN3 projects should coordinate the leasing of cross border dark fibers with NRENs. The goal is to avoid leasing expensive parallel fibre lines in the future, if using lambdas based on CBF self-interconnection is a sufficient solution.

D. EU should take appropriate steps to support national funding of research and educational network development and operation in Porta Optica Study beneficiary countries, **considering the recommendations included in Chapter 6 of this Deliverable.**

E. EU should take appropriate steps to support research of advanced networking technologies (including innovative new photonic technology, which substantially improves cost effectiveness) applied in wide-area networks. In the first step such support should be targeted at deployment of advanced programmable devices in research and education networks. This deployment will open new possibilities in network applications and network manageability. It can be seen as bottom-up step in building the Internet of the future, also enabled by successful development of photonic industry and open software systems. Leading position of Europe in such bottom-up networks improvement should be strengthened.

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9 Acronyms

ATLAS	Particle physics experiment
CAPEX	Capital Expenditure
CBF	Cross Border Fibre
CD	Chromatic Dispersion
CEF	Customer Empowered Fibre
CLA	CzechLight Amplifier
CWDM	Coarse Wave Division Multiplexing
DCF	Dispersion Compensation Fibre
DF	Dark fibre
DNS	Domain Name System
DWDM	Dense Wavelength Division Multiplexing
EDFA	Erbium Doped Fibre Amplifier
FBG	Fibre Bragg Grating
FE	Fast Ethernet
GBIC	Gigabit Interface Converter
GE	Gigabit Ethernet
GE	Gigabit Ethernet
GPRS	General Packet Radio Service
HTTP	Hypertext Transfer Protocol
ICMP	Internet Control Message Protocol)
IRU	Indefeasible Right of use
MAN	Metropolitan Area Networks
NF	Noise Figure
NIL	Nothing in line
NNTP	Network News Transfer Protocol
NOC	Network Operation Centre
NRC	Non-Recurring Charge
NREN	National Research and Education Network
OADM	Optical Add-Drop Multiplexer
OPEX	OPerating EXpenses
OTC	One Time Charge

PoP	Point of Presence
POP3	Post Office Protocol version 3
POS	Porta Optica Study
QUILT	Coalition of advanced regional network organizations in US
RMC	Recurring Monthly Charge
RON	Regional Optical Network
SFP	Small Form Factor Pluggable Transceiver
SLA	Service Level Agreement
SMTP	Simple Mail Transfer Protocol
SNMP	Single Network Monitor Protocol
STM	Synchronous Transfer Mode
STM	Synchronous Transport module
TCP	Transmission Control Protocol
TTS	Trouble Ticket Software
UBUNTUNET	The UbuntuNet Alliance is a regional research and education network in Africa
VAT	Value Added Tax
WDM	Wavelength division multiplexing
XENPAC	10 Gigabit Ethernet Pluggable Transceiver
XFP	10 Gigabit Small Form Factor Pluggable Transceiver

Appendix A NREN budget calculation

The following table group allows to switch to an Excel form by double click. Values describing projected network should be inserted to empty cells of the tables and then the cells containing zeros are calculated immediately. The number of table lines can be increased if needed, calculation formulas are adapted automatically. If predefined coefficients for calculation of maintenance costs, collocation costs, other operational costs and advanced research costs do not reflect the situation of NREN correctly, please use appriopriate coefficients or constants in adequate cells.

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Fibre budget table

PoP A	PoP B	Fibre length (km)	Use time (year)	Fibre acquiring cost (kE)	**Fibre cost per year (kE/y)**	Fibre cost per meter and year (E/m/y)	Contract type
					0,00	0,00	
					0,00	0,00	
					0,00	0,00	
Total		**0**			**0,00**	**0,00**	

Table of Overall NREN budget

Item	**Cost Category**	**Annualized costs (kE/y)**	**Percent**
1	**Transmission**	**0**	0,00
2	**PoP Equipment**	**0**	0,00
3	**Other operational**	**0**	0,00
4	**Advanced research**	0	0,00
	TOTAL	**0**	**100,00%**

Lighting budget table

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Use time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	**Lighting per year (kE/y)**	Lighting per m per y (E/m/y)	Tr. cost per m per y (E/m/y)
						0	0		**0,00**	0,00	0,00
						0	0		**0,00**	0,00	0,00
						0	0		**0,00**	0,00	0,00
Total		**0**	**0**			**0**	**0**	**0**	**0,00**	**0,00**	**0,00**

Transmission budget table for leased capacities

PoP A	PoP B	Distance on road (km)	Contract period (year)	Transmission cost (kE)	**Transmission cost per year (kE/y)**	Transmission cost per meter and year (E/m/y)	Service type
					0,00	0,00	
					0,00	0,00	
					0,00	0,00	
Total		**0**			**0,00**	**0,00**	

PoP equipment budget table

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	**PoP cost per year (kE/y)**
			0		0,00	0,00	0,00	**0,00**
			0		0,00	0,00	0,00	**0,00**
			0		0,00	0,00	0,00	**0,00**
Total	**0**		**0**		**0,00**	**0,00**	**0,00**	**0,00**

Table A.1: NREN budget computing table

Appendix B Example of open lighting design – comparison of three scenarios

Three examples of lighting cost for one fibre footprint

Scenario1 is a low cost solution with so called grey 1550 nm transceivers (GBIC, SFP, XENPAK, XFP) working up to 80 km, no DWDM multiplexors and demultiplexors and no compensation of chromatic dispersion.

Scenarios 2a and 2b use 1G or 10G DWDM transceivers with DWDM multiplexors and demultiplexors. OADMs have to be used if express (or transit or direct) lambdas are required. It is a more expensive but more flexible solution allowing easy additional upgrades.

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Usage time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m (E/m/y)	Tr. cost per m per y (E/m/y)
City G	City T	1	4	28	4	7	8	0	8	0,04	0,58
City G	City L	1	4	4	4	1	1	0	1	0,00	0,42
City G	City S	1	8	56	4	14	15	0	15	0,04	0,60
City G	City U	1	3	3	4	1	1	0	1	0,01	0,47
City L	City T	1	1	2	4	1	1	0	1	0,00	0,54
City G	City S	1	1	43	4	11	12	0	12	0,05	0,56
Total		6	21	136		34	37	0	37	0,15	0,65

Table B.1: Lighting budget table for Scenario1

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PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Usage time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m (E/m/y)	Tr. cost per m per y (E/m/y)
City G	City T	1	4	68	4	17	19	0	19	0,09	0,63
City G	City L	1	4	36	4	9	10	0	10	0,04	0,46
City G	City S	1	8	136	4	34	37	0	37	0,11	0,66
City G	City U	1	3	27	4	7	7	0	7	0,06	0,52
City L	City T	1	1	9	4	2	2	0	2	0,02	0,56
City G	City S	1	1	54	4	14	15	3	18	0,07	0,58
Total		6	21	330		83	91	3	94	0,39	0,90

Table B.2: Lighting budget table for Scenario 2a

PoP A	PoP B	Number of lambdas	Number of spans	TE costs (kE)	Usage time (year)	TE costs per year (kE/y)	TE&M costs per year (kE/y)	IL COLO cost (kE/y)	Lighting per year (kE/y)	Lighting per m (E/m/y)	Tr. cost per m per y (E/m/y)
City G	City T	1	4	98,5	4	25	27	0	27	0,14	0,67
City G	City L	1	4	62,5	4	16	17	0	17	0,07	0,49
City G	City S	1	8	176,5	4	44	49	0	49	0,14	0,69
City G	City U	1	3	35,5	4	9	10	0	10	0,08	0,54
City L	City T	1	1	9	4	2	2	0	2	0,02	0,56
City G	City S	1	1	54	4	14	15	3	18	0,07	0,58
Total		6	21	436		109	120	3	123	0,52	1,03

Table B.3: Lighting budget table for Scenario 2b

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Usage time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
Backbone	9	23	207	4	52	5	3	59,5
10 G capable	7	15	105	4	26	3	1	30,2
1 G capable	4	3	12	4	3	0,3	0,2	3,5
Total	20							93,2

Table B.4: Example of PoP equipment budget table for Scenario1

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Usage time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
Backbone	9	23	207	4	52	5	3	59,5
10 G capable	7	15	105	4	26	3	1	30,2
1 G capable	4	3	12	4	3	0,3	0,2	3,5
Total	20							93,2

Table B.5: Example of PoP equipment budget table for Scenario2a

Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Usage time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	PoP cost per year (kE/y)
Backbone	9	23	207	4	52	5	3	59,5
10 G capable	0							
1 G capable	11	3	33	4	8	1	0,4	9,5
Total	20							69

Table B.6: Example of PoP equipment budget table for Scenario 2b

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These examples show important possibilities of transmission system designed by open lighting approach for NREN in one of hypothetical countries with geographical dimensions similar to the Czech Republic. It is based on successful experience with the deployment of this type of transmission systems in CESNET, including cross-border lighting. This example was considered by experts of POS target countries before budget suggestion.

Information about topologies, requested transmission speeds etc. is adapted from Deliverable D2.1: Fibre footprint database and Deliverable D3.1: Case Studies.

In this example country, higher education and research institutions are situated in 6 towns outside the capital A – in cities B, C, D, E, F, G. According to the data received from questionnaires, 9 institutions in this country present advanced needs of higher priority. These organisations are located in A (priority 1), D, F, G and H. Slightly lower priority level – 2,5 was assigned to other 4 cities - C, E, F, I. Higher education institutions are located in 7 cities: A, B, C, D, E, F, G, 9 institutions present advanced needs: A, D, F, G, H, 4 cities with priority: C, E, F, I.

9 cities are therefore candidates for PoPs with high-end backbone routing/switching equipment: A, B, C, D, E, F, G, H, I. The remaining 11 cities may not require high-end equipment.

The routes with NREN development preference 1:

1. Route **A** – **I** – J – K – **G**: 4 spans, distance for this route would be ~ 200 km ie 50 km per span, 10 Gb/s.

2. Route **A** – **D** – L – M – **E**: 4 spans, distance for this route would be ~ 230 km ie 58 km per span, 1 Gb/s.

3. Route **A** – **H** – N – O – P – Q – R – **B** – **C**: 8 spans, distance for this route would be ~ 350 km ie 44 km per span, 10 Gb/s.

4. Route **A** – S – T – **F**: 3 spans, distance for this route would be ~ 125 km ie 42 km per span, 1 Gb/s.

Routes with NREN development preference 2:

5. Route **E** – **G**: 1 span, distance for this route would be ~ 125 km, 1 Gb/s.

6. Route **A** – **C**: 1 span, distance for this route would be ~ 250 km, 1 Gb/s.

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1 Scenario 1

A low cost or cost effective solution with so called “grey” 1550 nm transceivers (GBIC, SFP, XENPAK, XFP) working up to 80 km, no DWDM multiplexors and demultiplexors and no compensation of chromatic dispersion (only 2 routes require 10 Gb/s and distances among cities are up to 80 km). Optical amplifiers would be needed for route 6 only. In this scenario, any later upgrade will cause network drop outs.

For example, the route A – I – J – K – G will look as follows:

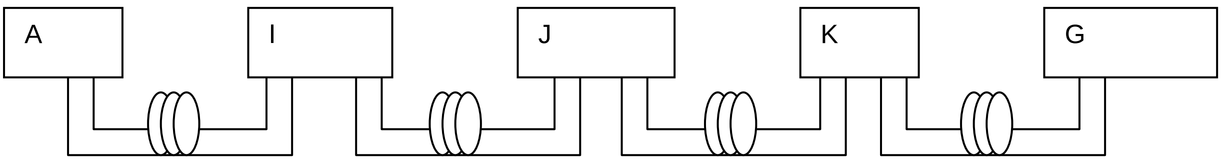

Figure B.1: Route 1 with 1550 nm 10 G transceivers, single channel

Only 10G transceivers for distances up to 80 kilometres are needed because average distances will be shorter (our assumption for 4 spans and the total length 200 km). But10 G equipment has to be located in every single location along the route – even in J and K, which are not candidates for PoP requesting 10G connectivity. The similar situation can be expected for routes 2, 3, 4 and 5.

The total distance for a backup route 6 is 250 km and it means optical amplifiers have to be deployed. A nothing in line (NIL) solution with 2 boosters (i.e. high power amplifiers) and 2 preamplifiers may work if GBICs or SFPs for distances 120 km or 140 km will be used (even 160 km SFPs have been announced). If parameters are worse then expected, inline amplifiers have to be deployed but it is connected with additional fees for housing of inline amplifiers somewhere along the line.

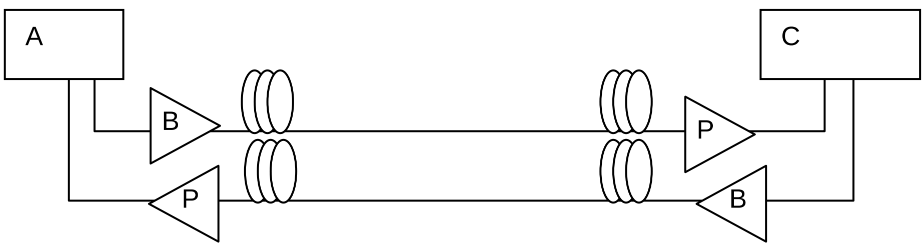

Figure B.2: Route 6, nothing in line solution with boosters and preamplifiers

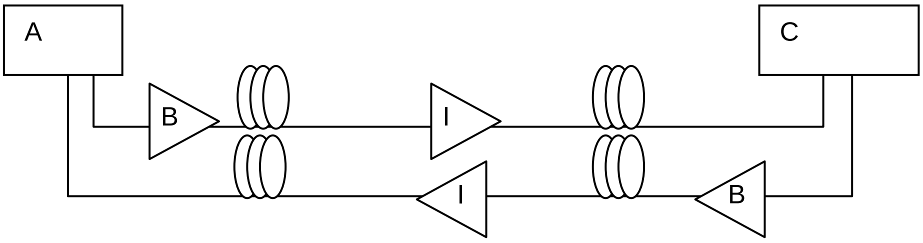

Figure B.3: Route 6, solution with inline amplifiers

2 Scenario 2

Here, 1G or 10G DWDM transceivers with DWDM multiplexors and demultiplexors are used. OADMs have to be used if express (or transit or direct) lambdas are required so we may call these two subvariants as Scenario 2a and Scenario 2b. The total number of lambdas in our calculations is 8, which should be enough for all NRENs associated with Porta Optica.

This Scenario 2 is more expensive but lambdas can be added later in a non-disruptive manner.

Again, as an example, the route A – I – J – K – G is presented here so a comparison with Figure B1 can be easily made.

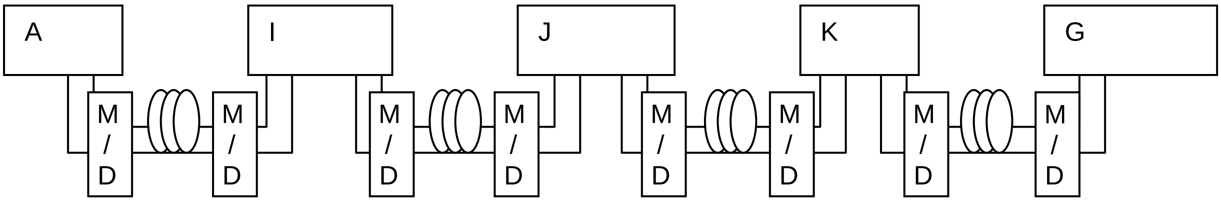

Figure B.4: Route 1 with DWDM 10 G transceivers and DWDM multiplexors and demultiplexors for Scenario 2a

Figure B.4 describes a point-to-point connection between adjacent nodes without OADMs and therefore express lambdas can not be implemented. A short explanation is needed here – as a matter of fact, it would be possible to implement express lambdas even with multiplexors and demultiplexors. It is demonstrated at Figure B5. An OADM can be regarded as a back to back configuration of a pair of demultiplexor and multiplexor. This pair can act as an OADM when appropriate demux outputs are manually connected with patchcords to appropriate mux inputs. This solution has one advantage – any number of lambdas can be added/dropped and

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the rest of lambdas can be used as express lambdas. Higher insertion loss and necessity to connect mux and demux ports manually is a disadvantage of this solution.

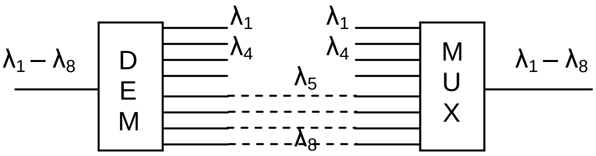

Figure B.5: A back to back configuration of a pair mux and demux: 4 lambdas (λ5 – λ8) are express and 4 lambdas (λ1 – λ4) are added/dropped

Because of additional losses of muxes/demuxes, it is unlikely that NIL can be implemented for Route 6 in this multichannel configuration and the solution with inline amplifiers will be required.

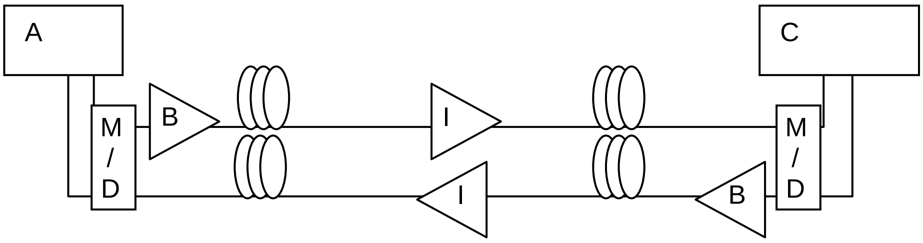

Figure B.6: Route 6, multichannel solution with inline amplifiers for Scenario 2a

If express lambdas are required for any reason, the situation will be more complicated if the total distance between nodes becomes longer then 80 km. In this case, a 10 G express signal will become too weak and chromatic dispersion will become another limiting factor. The solution is to deploy optical amplifiers and compensators of chromatic dispersion even for shorter sections of a route. For our purposes we'll use the Route 1 again.

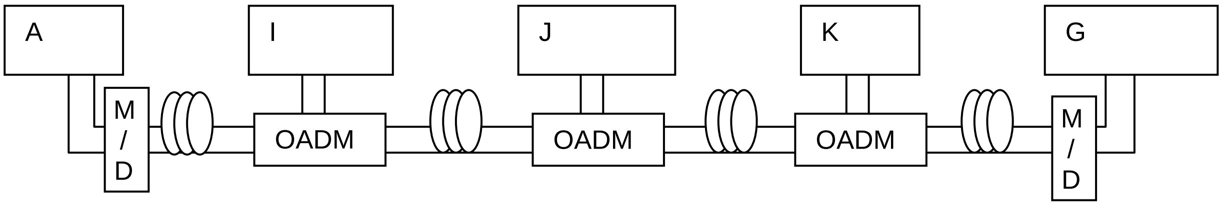

Figure B.7: Route 1 with DWDM 10 G transceivers and DWDM OADMs – optical amplifiers and compensators are required for express lambdas to work properly

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It was presented that the total distance for Route 1 is approximately 200 km and therefore single sections are considered to be 50 km long. It is clear that any express lambdas between non adjacent nodes have to travel more than 80 km and therefore amplifiers and compensators have to be deployed. It is difficult to present an exact number and type of optical amplifiers and compensators because it is strongly related to the attenuation of fibres and additional components (like OADMs and even different types of compensators have very different insertion losses). So Figure B.8 may represent one possible solution to this problem and it has to be considered that, for example, instead of boosters preamplifiers may be used. Different vendors use different equipment and, what may be even more important, different logic of principles of a network design.

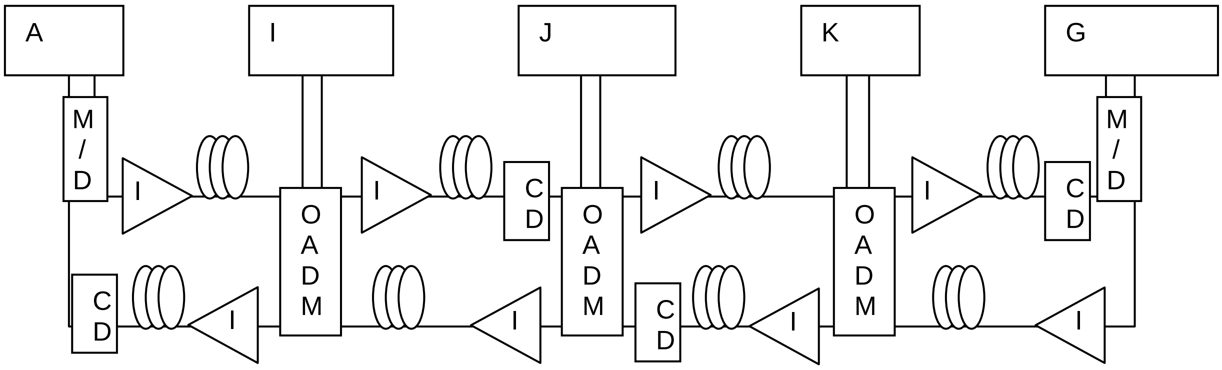

Figure B.8: Route 1 with DWDM 10 G transceivers and DWDM OADMs, amplifiers and compensators for Scenario 2b

Important points to notice for Figure B.8: a real configuration will look different and the number of optical amplifiers and compensators will vary. The reason is that two common compensators of chromatic dispersion (dispersion compensating fibres and fibre Bragg gratings) have quite a different insertion loss and the same refers to different types of OADMs. Some vendors prefer to deploy inline amplifiers or preamplifiers instead of boosters (lower output powers and prices). It can be expected that only 4 optical amplifiers will be needed to overcome all additional losses which means that the equipment will be cheaper. A more realistic schema is depicted in Figure B.9.

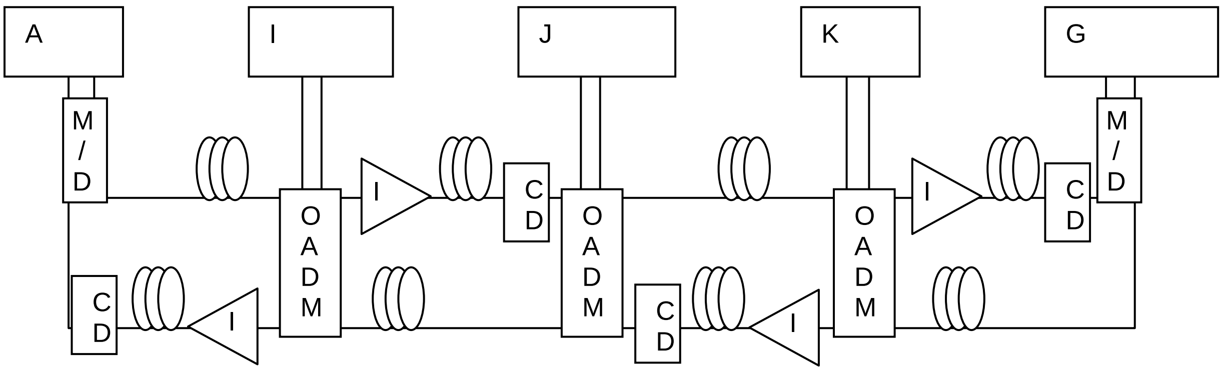

Figure B.9: More realistic schema for Route 1 with DWDM 10G transceivers and DWDM OADMs, 4 optical amplifiers and compensators for Scenario 2b

3 Results and price information for Scenario 1

It was decided to split all prices into two basic categories, just to make budgetary calculations simple:

- routing and switching equipment for all PoPs
- transmission equipment (transceivers, multiplexors, OADMs, optical amplifiers, compensators) for every dark fibre route.

Routing and switching equipment can be furtherer classified as backbone, 10G capable for all 10G routes and 1G capable for 1G routes. The results, if Vendor C is considered as an economic choice, are as follows:

- backbone PoPs
- PoPs with 10G capabilities
- PoPs with 1G capabilities.

type of PoP	number of PoPs	Price for Vendor C	total
backbone	9	23 000	207 000
10G capable	7	15 000	105 000
1G capable	4	3 000	12 000
Total price			324 000

Table B.7: The price of routing and switching equipment, Scenario 1

All calculations for Routes in Scenario1 are rather simple because only pluggable transceivers are needed (with one exception of Route 6). Based on price information available and summarized in Table 5.15 (buying transceivers from manufactures, not traditional vendors), the results are summarized in this table:

Route no	no of spans	no of 1G ZX transceivers	no of 10G ZR transceivers	no of boosters	no of preamps	prices
1	4	0	8	0	0	28 000
2	4	8	0	0	0	4 000
3	8	0	16	0	0	56 000
4	3	6	0	0	0	3 000
5	1	2	0	0	0	2 000
6	1	2	0	2	2	43 000
Total price						134 000

Table B.8: The price of transmission equipment, Scenario 1

Now a short price comparison can be made: if transceivers would be bought from a traditional vendor – the total price for transmission equipment is 239 000 euros i.e. the difference is more then 100 000 euros.

The total budget needed if Scenario 1 is going to be realized comes to 460 000 euros.

4 Results and price information for Scenarios 2a and 2b

The situation here is more complex. The price of routing and switching equipment for Scenario 2a is the same as for Scenario 1 (it is still a point to point configuration with DWDM multiplexers and demultiplexers added and therefore no compensation of chromatic dispersion is needed because the length of a link is less then 80 km). But for Scenario 2b, a design can be changed and 1G capable switching equipment can be deployed in all non-backbone 11 PoPs. Only backbone PoPs are connected with express 10G lambdas. That means compensators of chromatic dispersion and optical amplifiers have to be deployed which adds additional costs – the differences are illustrated in Figures B.3, B.6 and B.7. On the other hand, only cheaper switching equipment and cheaper 1G DWDM transceivers are needed.

The differences for this design can be illustrated with some help from Figures B.3 and B.7 which will be slightly modified here. Route 1 has 3 backbone PoPs – A, I and G. But in Scenario 2a all PoPs along the route have to be capable to work with 10G signals because there are no express lambdas allowing direct connection between A and I and between A and G (or I and G, of course). But it means only multiplexers and demultiplexers have to be deployed.

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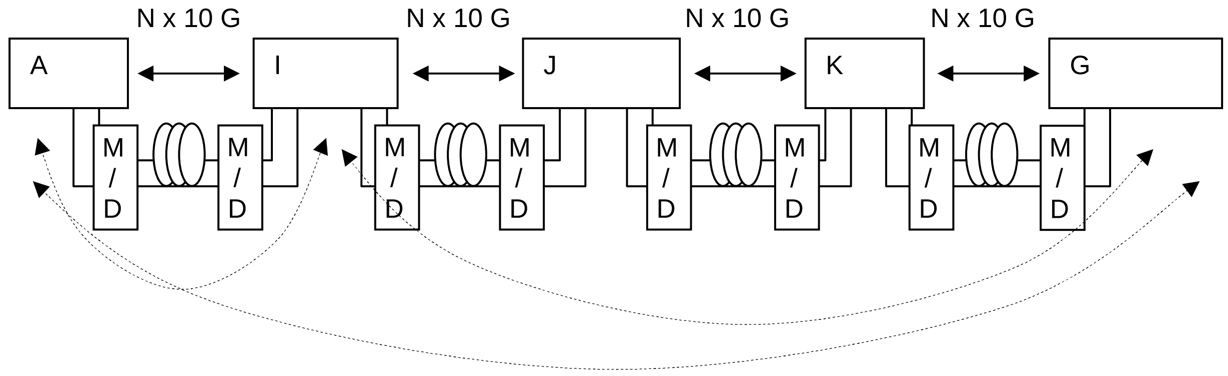

Figure B.10: Route 1 with 10G equipment in all PoPs without possibilities to deploy express lambdas (dashed lines) – Scenario 2a

Scenario 2b which allows for express lambdas is depicted in Figure B.11. From this figure it is clear this configuration is more complex with all requested additional optical amplifiers and compensators of chromatic dispersion. The number of mutual interconnections is therefore higher too – for example, all PoPs may be connected directly with A or may be connected to adjacent nodes. It makes all budgetary calculations really difficult and for Route 1 two 10G connections are considered A – I and I – G and two 1G connections I – J and K – J. Similar approach has been used for all other routes and budgetary calculations.

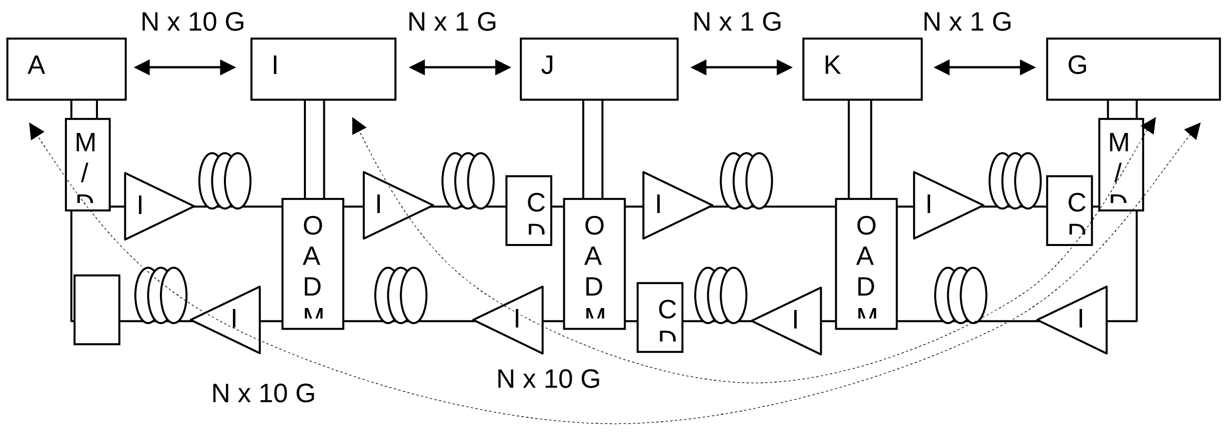

Figure B.11: Route 1 with 10 G equipment in 3 backbone nodes only – Scenario 2b

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Results and price information for Scenario 2a

The price of routing and switching equipment is exactly the same as for Scenario 1, as described in the previous paragraphs.

type of PoP	number of PoPs	Price for Vendor C	total
Backbone	9	23 000	207 000
10G capable	7	15 000	105 000
1G capable	4	3 000	12 000
Total price			324 000

Table B.9: The price of routing and switching equipment, Scenario 2a

Calculations for transmission equipment are rather uncomplicated because only DWDM multiplexors and demultiplexors are added (only one exception is the solution with inline amplifiers implemented for Route 6 as described in previous paragraphs – NIL solution will not probably work because of additional losses of multiplexors).

Route no	no of spans	no of 1G DWDM TRX	no of 10G DWDM TRX	no of boosters	no of inlines	no of muxes	prices
1	4	0	8	0	0	8	68 000
2	4	8	0	0	0	8	36 000
3	8	0	16	0	0	16	136 000
4	3	6	0	0	0	6	27 000
5	1	2	0	0	0	2	9 000
6	1	2	0	2	2	2	54 000
Total price							330 000

Table B.10: The price of transmission equipment, Scenario 2a

The total budget needed if Scenario 2a is going to be realized comes to 654 000 euros.

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Results and price information for Scenario 2b

The price of routing and switching equipment is different here because express lambdas allow for using 1G equipment in all non backbone nodes.

type of PoP	number of PoPs	Price for Vendor C	total
backbone	9	23 000	207 000
1G capable	11	3 000	33 000
Total price			240 000

Table B.11: The price of routing and switching equipment, Scenario 2b

By contrast, calculations for transmission equipment are much more complicated because a solution with OADMs gives more freedom how to design all 1G and 10G connections. The number of optical amplifiers and compensators may vary for actual routes and for a real design it is absolutely necessary to know real parameters like lengths of routes, fibre losses etc.

Route no	no of spans	no of 10 G DWDM TRX	no of 1G DWDM TRX	no of muxes	no of OADMs	no of OAs	no of CDs	prices
1	4	4	4	2	3	4	4	98 500
2	4	0	8	2	3	4	0	62 500
3	8	6	10	2	7	8	8	176 500
4	3	0	6	2	1	2	0	35 500
5	2	0	2	2	0	0	0	9 000
6	2	0	2	2	0	4	0	54 000
Total price								436 000

Table B.12: The price of transmission equipment, Scenario 2b

The total budget needed if Scenario 2b is going to be realized comes to 676 000 euros.

Now some summary and conclusions can be presented. Table B.13 illustrates the price differences among individual scenarios 1, 2a and 2b.

	Routing/switching equipment	Transmission equipment	Total price
Scenario 1	324 000	134 000	458 000
Scenario 2a	324 000	330 000	654 000
Scenario 2b	240 000	432 000	676 000

Table B.13: Price comparison for all three scenarios

Scenario 1 is the most cost effective but any later upgrade will cause a network breakdown. Scenarios 2a and 2b are comparable from an economic point of view. If more lambdas are going to be deployed, Scenario 2 should start to pay off.

One more important notice: partial prices for photonics transmissions for this hypothetical example are different then the prices introduced in Tables 4.1, 4.2, 4.3 and 4.4. The reason is that all calculations for tables 4.x are done for NIL scenarios from 100 km to 200 km or in case of multihop scenarios for spans of 100 km or 120 km. On the other hand, spans from this example range from 42 km (Route 4) to 125 km (Route 5) which implicates that more transmission components (Table 5.15) have to be deployed. It means that for the first version of a budget, prices of photonics transmissions from Tables 4.x can be used. If a budget has to be calculated more precisely, directions and scenarios from Appendix B have to be taken into account.

Item	Cost Category	Annualized costs (kE/y)	Percent	Note
1	*Transmission*	689	73.17%	
2	*PoP Equipment*	93	9.87%	
3	*Other operational*	160	16.99%	
4	*Advanced research*	0	0%	
	TOTAL	942	100%	

Table B.14: Example of table of NREN budget for Scenario1

Item	Cost Category	Annualized costs (kE/y)	Percent	Note
1	*Transmission*	743	73.68%	
2	*PoP Equipment*	93	9.23%	
3	*Other operational*	171	16.98%	
4	*Advanced research*	0	0%	
	TOTAL	1007	100%	

Table B.15: Example of table of NREN budget for Scenario2a

Item	Cost Category	Annualized costs (kE/y)	Percent	Note
1	*Transmission*	772	76.21%	
2	*PoP Equipment*	69	6.81%	
3	*Other operational*	169	16.68%	
4	*Advanced research*	0	0%	
	TOTAL	1013	100%	

Table B.16: Example of table of NREN budget for Scenario2b

Another chapter is CBF connections to other countries. 7 possible routes are available in this example country with fibre distances from 30 km to 350 km. With CBF connections, other than technical issues may be considered, and therefore it is more difficult to propose a feasible route. If it is possible, shortest routes with distances up to 80 km (for 10 Gb/s) or 140 km (for 1 Gb/s) are the most convenient because only transceivers are needed. NIL solution can be deployed for distances up to 200 km (or more because it is dependent on the quality of fibres) so this distance may be the longest recommended fibre distance for a CBF route. NIL solutions can be recommended for CBF routes as the most feasible ones. More information and description can be found on the CESNET web site:

http://www.ces.net/doc/press/2006/pr061106.html and

http://www.ces.net/doc/press/2006/pr060216.html.

Price estimations for CBF connections can be done with some help from previous examples.

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Appendix C PIONIER management system description

Network management model

All NRENs rely on network devices to provide connectivity. This involves not only IP routers but also switches or transport network devices like DWDM equipment. These network elements must remain healthy in order for a network to operate and the Network Operation Center (NOC) must know their status. Due to increasing complexity of the networks more and more vendors are becoming installed and NRENs are becoming heterogenous now. This is obvious that due to quantity and complexity of today's infrastructure the task of network management cannot be performed manually and specific monitoring software must be used to ensure that the network is working properly.

The OSI network management model defines five areas of network management:

- Fault Management
- Configuration Management
- Performance Management
- Security Management
- Accounting Management

In addition to choosing an area of network management (as most of the organizations need to monitor various technologies from multiple vendors) it must be made clear that only one standard has been implemented to support most of the network equipment and is commonly used within NOCs. This is Simple Network Monitoring Protocol (SNMP) which is the industry and platform neutral standard (RFC 1157). For these reasons using SNMP by NOCs is a pre-requisite for any system monitoring.

There is a variety of paths for choosing an appropriate network monitoring solution for research networks but the basic one is to start with the first area of fault management. This involves tracking events and alarms, fault logging and problem identification and solution help. These items should therefore influence the decision to choose network monitoring solutions to be deployed within NREN's NOC.

1 Network Operation Center

NOC is a monitoring center equipped with software tools and managed by dedicated support engineers in order to ensure continuous network operation. In the best case it should operate 24 hours a day, 7 days a week but it could also operate during business hours only, having engineers on duty on the phone outside these hours and during weekends and public holidays. The final solution depends on network complexity and the services NREN wants to offer.

The NOC with its tools should provide the following capabilities:

- Monitoring all backbone links and network devices
- Ensuring continuous operation of services
- Providing support for customers
- Troubleshooting of all network and system related problems
- Opening tickets to track problems

All problems should be recorded by the center's engineers and (provided an appropriate tool is used) a trouble ticket number should be assigned in order to follow-up the problem.

In addition to basic fault management NREN NOC could provide performance monitoring based on verifying the Quality of Service (QoS) and Service Level Agreements (SLAs). Other possible services include configuration management which collects, maintains and restores network equipment configurations and inventory management which maintains equipment parts' database.

2 Network monitoring solutions

There are many network monitoring solutions to start with. Basically one can choose among a high-end enterprise solutions and low-end tools. The other factor is whether a system is web-based or not. By making tools available remotely via a web browser administrators can access it more quickly from any place. Moreover, some of the tools available on the market offer some functionality only through a web interface.

When choosing an appropriate network monitoring tool the following items should be considered as important and helpful functionalities in the package:

- Automatic discovery of network nodes and their configuration
- SNMPv1 and v2 support
- Automatic data collection using SNMP
- SNMP trap handling
- Configuration done within a simple user interface rather than script-based interface

Choosing between high-end and low-end tools is also a question of scale. While free applications can support tens of nodes and require less effort in deploying, commercial systems can support thousands of nodes and require proper configuration and well skilled personnel.

To start with, NOC could consider using open source and freely available tools. We could suggest two of them:

- Nagios
    - Nagios is a host and service monitor (SMTP, POP3, HTTP, NNTP, PING). It has been designed to run under the Linux operating system, but works fine under most *NIX variants as well. The monitoring daemon runs intermittent checks on hosts and services and returns status information to Nagios. When problems are encountered, the daemon launches a visible alarm and can send

notifications out to administrative contacts e.g. via email. Current status information, historical logs, and reports can all be accessed via a web browser.
  - More information: http://www.nagios.org/

- The Dude

  - The Dude automatically scans all devices within specified subnets, draws and lays out a map of networks, monitor services and issues an alert in case some service have problems. The Dude also supports SNMP, ICMP, DNS and TCP monitoring for devices that support these procotols.
  - More information: http://www.mikrotik.com/thedude.php

When a more sophisticated solution is required the NOC can consider the following commercial monitoring applications:

- IPSWITCH WhatsUp Gold
- HP OpenView Network Node Manager
- IBM Tivoli NetView

The last two applications mentioned above discover TCP/IP networks, display network topologies, correlate and manage events and SNMP traps, monitor network health, and gather performance data. Their flexible architecture, customization and additional plug-ins meet the needs of managers of large networks with many services running. If the NREN is running equipment of various vendors it is even possible for many of them to integrate their proprietary management applications (e.g. for managing Cisco devices or DWDM equipment) under one umbrella of HP OpenView or Tivoli NetView. This makes the life of NOC easier and facilitates problem resolution.

For the NREN NOC it may be important to collect data which allow both historic and near real-time visualization of performance statistics. This may include link utilization or round-trip delay. Together with network status monitoring applications it gives operators a complete picture of what is happening on the network. With the use of the most popular and available for free The Multi Router Traffic Grapher (MRTG) one can typically gather data every 5 minutes (subject to configuration) and present data over a longer period of time (days, weeks, months). This historical view on the data offers understanding the network and link performance over a period of time. It can also help in planning network upgrades.

The final important element of NOC is the trouble ticket software (TTS) which, upon a network fault, will allow to submit a message (ticket) and monitor its progress. Then it is broadcasted via e-mail notifications or Web access to all service operators and other involved parties to notify them about this problem and help to track it.

For more information about network monitoring software look at the EMANICS repository of network management software at www.emanics.org

Appendix D Call for the lease service of a circuit

Name of the organization

Registered office: ………………..

Identification no.: ………..

registered with …………….

"Call for the lease service of a circuit A - B"

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Document Code: POS-15-001v3

1 Basic information

1.1 Basic entries

Name:

Registered office :

Identification no.:

Tax Id. no.:

The Organization announces this call according to the Art….. par….

1.2 Contact person

The contact person for all the matters related to this call is .....,

fax: .....,

e-mail: .....

2 Subject matter of the call

The subject matter of this call is the lease service of the circuit between the A-B points as mentioned hereinafter. The circuit can be made as a leased digital circuit, a lease of a pair of optical fibres or one fibre.

End points of the circuit are mentioned here:

A	B
Location A	Location B

Addresses of the end points of the circuit and contacts for the responsible persons:

Point	Address (location, floor, room) and contact (name, e-mail, tel.)
Location A	
LocationB	

2.1 The lease of a digital circuit

In case of the lease of a digital circuit the transmission will be made fully by optical fibres or, if possible, at least by optical fibres with the exception of the first mile to point B, which will be made by a microwave connection. Demanded transmission capacity is at least 10Mbps with FE interface and with a possibility of upgrade up to 1Gbps with GE interface.

Within your tender offer of the lease of a digital circuit especially these points should be mentioned:

a) The length of used fibres (even if zero)
b) The amount of microwave steps and their length
c) The start date of the lease of the line
d) The possibility to lay down the optical cable of the first mile (length, approximate price, necessary period of realization) in case the Organization decides to rent the fibres between A-B points in the future.
e) Prices for capacity upgrades among the 10Mbps to 1Gbps

2.2 The lease of pair or one optical fibre

Within your tender offer of the lease of pair or one optical fibre especially these points should be mentioned:

a) The complete length of the fibre, complete expected attenuation and dispersion (if the measured values are not available, it is necessary to mention expected values)
b) For each span of the line mention the owners of the fibres and if the optical cable is placed underground or above ground (on poles).
c) The start date of the lease of the complete line
d) The earliest possible start date of projecting and realization.

In all the cases (i.e. in cases of article 2.1 and 2.2) the Organization requests that the supplier is the lessor of the whole line between the end points of connection.

3 Date and course of performance

The Organization supposes provision of the service for an indefinite period of time.

Within your tender suggested start date of provision of the service soulde be mentioned (at the latest ....). In case of the lease of fibres it is necessary to deliver the service to users for tests at least 3 working days in advance. Also the protocol of the measurement of attenuation and chromatic dispersion of the complete line and the document with the specification of the optical splitter and numbers of the terminals of the each end point of the line should be supplied. The Organization is authorized not to accept the service, if the line does not fulfill the parameters stipulated in the contract or if the Organization does not receive all the documents mentioned above.

4 The pricing process method

4.1 Basic requirements

The total price will be specified in the tender as the highest acceptable price for the performance of the call, including all the fees and all other costs related to the performance of the call.

The price will be specified in the tender in following way:

1. Total price for the performance of the call [a sum of prices in accordance with 2.a) and b)]

2. a) nonrecurring setting up charge

   b) monthly charges for indefinite period upon mutual obligation of the parties not to terminate the service within a period of ….. (alternatives 1, 2, 4 or more years).

The price will be specified in … (currency) in following way:

- the price without VAT,
- rate of VAT - %,
- price including VAT.

The Organization prefers higher setting up charge and lower monthly charges, if it leads to a more favorable total price for the performance of the public contract (see 1.).

4.2 Conditions to exceed the price

The price could be exceeded only in connection with the change in tax regulation concerning VAT.

5 Payment conditions

The Organization will obligate to pay the monthly charges after the commencement of the provision of the service.

The supplier is authorized to demand the setting up charge before the commencement of the service usage.

All charges are payable by a bank transfer to the bank account of the supplier on the basis of a tax document - an invoice issued by the supplier.

6 Requested business terms

6.1 Within your tender the earliest possible date of the conclusion of the agreement and the start date of projecting and realization should be mentioned.

6.2 Sanctions on the supplier due to a breach of contract shown in percentage of a monthly charge without discounts must be at least as the following:

monthly availability is less than	percentage rate of a regular monthly price
99,6 %	10 %
99,3 %	15 %
99,0 %	20 %
98,0 %	25 %
97,0 %	30 %
96,0 %	100 %

In case of delay of the date of the line installation the sanction on the supplier amounts to at least 110% of the daily price for each complete day of the delay.

6.2.1. The supplier will offer a draft agreement within the tender offer, or an appendix (specification) to an existing agreement on lease of dark fibres.

6.3 The draft agreement must not exclude or in any way reduce the rights or requirements of the Organization stated in this call.

6.4 In the draft agreement the supplier must accept the right of the Organization to terminate the agreement immediately in case of supplier's delay in performance of the contract or its parts and conditions for a period longer than 15 days or in case of repeated delay within one month.

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7 Tender offer

7.1 Send the electronic form of the tender offer to e-mail: ……………..

7.2 The supplier is obligated to deliver the tender offer at the latest to ……………..

7.3 The tender offer must be executed in ………….. language.

7.4 The supplier is bound by its tender offer until: ………………..

8 Rights of the Organization

8.1 The Organization reserves the right not to take into account a tender, which does not correspond with the requirements stated in this call, or which is not complete.

8.2 The Organization reserves the right to cancel the call without specifying any reasons.

8.3 The Organization reserves the right to verify any information provided by the supplier by a third party and related to this the supplier is obligated to provide the Organization with all necessary cooperation.

At ………….. on ………………..

Appendix E Call for the lease of fibre or lambda

Name of the organization **Registered office: ……………….** **Identification no.: ………..** registered with ……………. **“Call for the lease of fibre or lambda A - B“**

1 Basic information

1.1 Basic entries

Name:

Registered office :

Identification no.:

Tax Id. no.:

The Organization announces this call according to the Art….. par….

1.2 Contact person

The contact person for all the matters related to this call is .....,

fax: .....,

e-mail: .....

2 Subject matter of the call

The subject matter of this call is the lease of the dark fibre or lambda between the A-B points as mentioned hereinafter. The circuit can be made as a leased digital lambda circuit, a lease of a pair of optical fibres or one fibre.

End points of the circuit are mentioned here:

A	B
Location A	Location B

Addresses of the end points of the circuit and contacts for the responsible persons:

Point	Address (location, floor, room) and contact (name, e-mail, tel.)
Location A	
LocationB	

2.1 The lease of lambda

In case of the lease of a lambda, demanded transmission capacity is 10 Gb/s.

Within your tender offer of the lease of a digital circuit especially these points shuld be mentioned:

a) The length of used fibres
b) Lambda type (pure optical, SDH framing, Ethernet framing,..) and interface
c) The start date of the lease
d) Possibilities and prices for capacity upgrades (two or more lambda lease)

2.2 The lease of pair or one optical fibre

Within your tender offer of the lease of pair or one optical fibre especially these points shuld be mentioned:

a) The complete length of the fibre, complete expected attenuation and dispersion (if the measured values are not available, it is necessary to mention expected values)
b) For each span of the line the owners of the fibres and if the optical cable is placed underground or above ground (on poles) should be mentioned.
c) The start date of the lease of the complete line
d) The earliest possible start date of projecting and realization.

In all the cases in 3.2, the Organization requests that the supplier is the lessor of the whole line between the end points of connection.

3 Date and course of performance

The Organization supposes provision of the service for an indefinite period of time.

Within your tender suggested start date of provision of the service soulde be mentioned (at the latest ....). In case of the lease of fibres it is necessary to deliver the service to users for tests at least 3 working days in advance. Also the protocol of the measurement of attenuation and chromatic dispersion of the complete line and the document with the specification of the optical splitter and numbers of the terminals of the each end point of the line should be supplied. The Organization is authorized not to accept the service, if the line does not fulfill the parameters stipulated in the contract or if the Organization does not receive all the documents mentioned above.

4 The pricing process method

4.1 Basic requirements

4.1.1 The total price will be specified in the tender as the highest acceptable price for the performance of the call, including all the fees and all other costs related to the performance of the call.

4.1.2 The price will be specified in the tender in following way:

4.1.3 Total price for the performance of the call [a sum of prices in accordance with 2.a) and b)]

a) nonrecurring setting up charge

b) monthly charges for indefinite period upon mutual obligation of the parties not to terminate the service within a period of ….. (alternatives 1, 2, 4 or more years).

4.1.4 The price will be specified in … (currency) in following way:

4.1.5 the price without VAT,

4.1.6 rate of VAT - %,

4.1.7 price including VAT.

4.1.8 The Organization prefers higher setting up charge and lower monthly charges, if it leads to a more favourable total price for the performance of the public contract (see 1.).

4.2 Conditions to exceed the price

The price could be exceeded only in connection with the change in tax regulation concerning VAT.

5 Payment conditions

1. The Organization will obligate to pay the monthly charges after the commencement of the provision of the service.
2. The supplier is authorized to demand the setting up charge before the commencement of the service usage.

All charges are payable by a bank transfer to the bank account of the supplier on the basis of a tax document - an invoice issued by the supplier.

6 Requested business terms

6.1 Within your tender the earliest possible date of the conclusion of the agreement and the start date of projecting and realization should be mentioned.

6.2 Sanctions on the supplier due to a breach of contract shown in percentage of a monthly charge without discounts must be at least as the following:

monthly availability is less than	percentage rate of a regular monthly price
99,6 %	10 %
99,3 %	15 %
99,0 %	20 %
98,0 %	25 %
97,0 %	30 %
96,0 %	100 %

In case of delay of the date of the line installation line the sanction on the supplier amounts to at least 110% of the daily price for each complete day of the delay.

6.3 The supplier will offer a draft agreement within the tender offer, or an appendix (specification) to an existing agreement on lease of dark fibres.

6.4 The draft agreement must not exclude or in any way reduce the rights or requirements of the Organization stated in this call.

6.5 The draft of the agreement must be signed by statutory authority, or by another warranted representative; in this case the original or officially authenticated copy of this authorisation must be attached to the draft of supplier’s agreement.

6.6 In the draft agreement the supplier must accept the right of the Organization to terminate the agreement immediately in case of supplier’s delay in performance of the contract or its parts and conditions for a period longer than 15 days or in case of repeated delay within one month.

6.7 The supplier is bound to include the Companies Register abstract or other evidence according to appropriate legal regulations. The Companies Register abstract or other evidence must not be older than 3 months. The supplier is also bound to prove qualification for all the matters that are the subject of this call. All the documents must be delivered as originals or officially verified copies.

This is not mandatory in case, when the supplier delivered these documents to the Organization within another call for tenders and these documents fulfil the conditions mentioned above at the term determined for delivering the offer.

7 Qualifying criteria for the offers

The offers will be evaluated according to economic convenience and according to the criteria mentioned below with downgoing weight of importance.

1. Total price of the offer without VAT and the efficiency of the service for the user - weight 50%
2. Technical parameters and experience with the supplier - weight 40%
3. The term of performance of the service - weight 10%

Ad 1. The Organization prefers fibre rental to digital circuit rental for possible implementation of higher number of digital circuits within the usage of the fibre. This preference will not be used in case when the offer for fibre rental includes expensive construction of the first mile. The organization will multiply the offered prices for digital circuit rentals 6 (six) times for the purpose to compare with offered rental prices.

Ad 2. According to lower reliability the Organization will evaluate lines with three and more microwave steps as unsatisfactory and the lines with one or two microwave steps will be evaluated according to the length of their microwave steps (total length more than 40 km as unsatisfactory again).

8 Tender offer

8.1 Deliver the tender offer in three counterparts (one original and two copies) in a closed envelope designated with the name "………..", the stamp and the address of the supplier. The supplier must specify an explicit contact address for written communication between the supplier and the Organization. All the pages of the offer, or more precisely of each counterpart, will be numbered continuously in an upgoing manner. The supplier will deliver the offer also in an electronic form on CD. The draft of the contract in an electronic form will be delivered in MS Office or compatible format.

8.2 The supplier is obligated to deliver the tender offer at the latest till …………….. to the address of …………….

8.3 The tender offer must be executed in ………….. language.

8.4 The supplier is bound by its tender offer until: ………………..

9 Rights of the Organization

9.1 The Organization reserves the right not to take into account a tender, which does not correspond with the requirements stated in this call, or which is not complete.

9.2 The Organization reserves the right to cancel the call without specifying any reasons.

9.3 The Organization reserves the right to verify any information provided by the supplier by a third party and related to this the supplier is obligated to provide the Organization with all necessary cooperation.

At ………….. on ………………..

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