03.07.07

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

Contractual Date:	**30.04.2007**
Actual Date:	01.07.2007
Contract Number:	026617
Instrument type:	SSA
Work Package	WP3
Nature of Deliverable:	R (Report)
Dissemination Level	PU (Public)
Lead Partner	CESNET
Document Code	POS-15-001

Authors: Stanislav Sima (editor), Lada Altmannová, Peter Bogatencov, Jiří Burian, Bartlomiej Idzikowski, Baiba Kaskina, Eugene Khodosov, Oksana Kubichka, Ramaz Kvatadze, Urmas Lett, Mikhail Makhaniok, Anne Mardimae, Bruno Martuzans, Arthur Petrosyan, Valentin Pocotilenco, Milosz Przywecki, Jan Radil, Wojciech Sronek, Robert Tadevosyan, Raimundas Tuminauskas, Chrysostomos Tziouvaras, Gajane Valchevskaja, Josef Vojtech

Abstract

Deliverable references results of SEEFIRE project, which represents traditional approach to fibre network budgeting and economical analysis. Based on SEEFIRE project and NREN development in its beneficiary countries in South-East Europe was recognized, that main barrier of NREN development is low level of funding from the state or public budget. For this reason, economical 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 first time in such level of details and comparison with traditional approach is made. Mixed photonics and traditional approach is also possible and was proved by CESNET and SWITCH at least. Budget recommendations for beneficiary countries are done in dependence on recognized local possibilities. Important recommendation for state governments in beneficiary countries as well as for EC is given. Deployment of photonic industry product in research wide area networks should be supported as first step of technology transfer for photonics deployment in communications.

The Porta Optica Study project is funded by the European Commission under the FP6 contract no. 026617. This document contains material which is the copyright of Porta Optica Study contractors and the EC, and may not be reproduced or copied without permission. The information herein does not express the opinion of the EC. The EC is not responsible for any use that might be made of data appearing herein. The information in this document is provided as is and no guarantee or warranty is given that the information is fit for any particular purpose. The user thereof uses the information at its sole risk and liability.

Project:	Porta Optica Study
Deliverable Number:	D3.2
Date of Issue:	03/07/07
EC Contract No.:	026617
Document Code:	POS-15-001

Table of Contents

Table of Figures and Tables

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

1 Introduction

This deliverable provides results of the analysis of economical issues of fibre network deployment and operations and suggestions of the financial rules governing the building and operation of the networks, agreed by project partners.

Dark fibre NREN is relatively new concept and should be well understood in order to properly evaluate the economical aspects of such infrastructure development. Fibre acquisition and operations involve new cost categories that have to be recognized and added to the economical model of operations of future fibre based NRENs. Also the economical assessment shall be done for 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 economical 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 connectivity 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 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 of open software) and substantially improves cost effectiveness. 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 optika 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.

It opens new area of collaboration of NRENs with photonic industry and photonics research clusters [21, 22, 23], 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 Description of Fibre footprint database and connectivity used by NRENs in target countries, which was collected for Deliverables D2.1 and D3.1 [10].

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

In SEEFIRE project was elaborated Deliverable D3.2: Economic Model for the Acquisition and Operation of Dark Fibre Networks in SE Europe. 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 estimates 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 work carried out in the GÉANT2 procurement enables more detailed comparisons of different routes to be made and concerns especially by question if dark fibre using in research and education networks are economically reasonable. It was “big question” in time of GÉANT2 preparation and procurement, despite of decision of many European NRENs before to use dark fibres. Difference was seen mainly in distances to be overcome by fibres. Important question was if it is more cost effective to lease fibres comparing with leasing of some number of lambdas. It is very difficult to say, what number of lambdas will be needed in given line in the future, any assumption can be quite wrong. Despite of this, the second SEEFIRE model gives insight into details of this issue. Indirect result is technical feeling, that fibre lighting should be solved by transmission systems allowing step-wise extensions and improvements, not by systems making additions of lambdas expensive and making change of the maximum acceptable number of lambdas even more expensive.

In time of writing POS project proposal was widely accepted, that research networks should be based on dark fibres, and project ask to use it if possible. Indirect confirmation of this strategic design 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 point of view is needed to update costs used, to use costs relation valid for POS countries and take into account new results of photonic industry. This is done in following text in details, new cost tables are collected and new calculation tables are developed.

Important experience with SEEFIRE project result is, that main barrier of NREN development is low level of funding from the state or public budget. This means budgets suggested in chapter 6 should be economical as much as possible and step-wise improvements of topology and equipment should be supposed. Cost effectiveness should be achieved by usage of dark fibres and advanced photonic technology.

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

3 Cost of dark fibre footprint

3.1 Factors affecting the cost of the dark fibre footprint

A list of the parameters affecting the contracting for dark fibre is provided at deliverable 3.2 of the SEEFIRE project [3]. At 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 an NREN to be responsible for the maintenance of the dark fibre footprint. This is not only because of lack of relevant technical expertise but mainly because extensive human network is required and in many cases expensive equipment. Moreover for restoring submarine fibre cuts, a ship with specialised equipment must be hired so as to fix the problem; usually DF owners outsource this task to relevant companies.

For these reasons, NRENs include maintenance services as 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, an 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 nodes where NREN clients are aggregated but also to nodes that serve for regenerating/amplifying the optical signal. In this case, NRENs must include collocation services at 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 do with 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 bidirectional lambda – one for each direction. Overall number of wavelengths for transmission in fibre is technically and physically limited, but real fibre lines are seldom full up to limit.

It is also possible that an NREN acquires a contract for more than one pair of DF. By this way, an 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 costs of additional fibre pairs. It can be effective, if new cable line is constructed for NRENs (cost of line and maintenance cost are nearly the same for different number of fibres), but probably not if NREN lease fibres.

In order to sum up, acquiring a single pair of DF and deploying DWDM transport equipment is the most usual solution and using of single fibre looks like possible improvement of cost effectiveness for fibre lessees. Cost of single fibre lighting and reliability of transmission are discussed in next chapter.

3.1.5 Duration of the contract

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

3.1.6 "Geography" of the fibre footprint

Not all fibre links cost the same; their cost follow the rules of the "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 first case DF supply is expected to be greater and this drives prices down.

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. Wholesale purchase of dark fibre has normally been accomplished by means of IRUs.

The IRU contact defines detailed technical and performance specifications for the IRU fibres. More specifically it includes DF acceptance and testing procedures, 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 then 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 that the IRU grantor falls to bankruptcy or even the case of mergers or acquisitions. In the first case the IRU user must have the right to terminate the contract and in the second 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 is price of FiberCo for research networks $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 are higher (up to about 1 E/m/y).**

IRU is considered asset in some countries and IRU front payments is CAPEX, so in tax calculation annual depreciation only is taken, resulting potentially in higher tax payment (but tax calculation depends on annual lost and profit sheet of organisation, possible national tax exceptions for non-profit activities etc.). Based on that 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 special case in law system and in tax rules and is contracted as long term fibre lease including O&M. In some cases are possible to support cable line construction from EU Structural Funds and use IRU-like contract for support of 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 recommended what knowledge about existing and available fibres and services are 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 fibre owner company - oil transit company. Subject of contract is research cooperation (evaluation of some new usage possibilities, etc.). 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 has 4.830 km leased dark fibres including 370 km of single fibre lines now. Dark fibre lines are contracted with oil transit company, railway company, network infrastructure provider and telecommunication companies. Diversification of fibre leasing to about 8 fibre lessors is proved to be economical advantage for CESNET, including more labour on contracting needed. Important advice is to have one provider for one PoP to PoP line, but to ask information about owners of subcontracted fibre segments.

Procurement, contracting and paying CBF

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

CESNET uses three CBF lines presently.

The first was dark fibre line **Brno (CZ) - GE Bratislava (SK)** over 190km since 2003. This line is using new advanced photonic products CLA PB01 with the 4-channel DWDM Mux/demux since February 2006. CESNET contracted with network infrastructure provider to lease Czech part of this dark fibre line Brno – Hrusky near border CZ – SK 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 own expenses. In the initial stage, switch was deployed in Hrusky and each NREN was monitoring 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) about 74 km is in operation since 2004. This line has been equipped DWDM 32 x 10 Gb/s. CESNET has leased Czech part of line Ostrava – Cieszyn 71km long from telecommunication company. Maintenance of Czech part is included in monthly price of leasing. Poland dark fibres of this CBF line are property of PSNC. This means covering of expenses for dark fibre is is exactly “each up to border”. Monitoring of CZ – PL CBF is different: CESNET DWDM equipment is housed in polish side in Cieszyn and connected back to back with Pionier DWDM equipment, so CESNET is monitoring whole line. Above this, CESNET and PSNC has implemented in CESNET2 network and in Pionier network monitoring for new GEANT2 lambda **Praha-Poznan** going via that CBF.

Another CBF line **Brno (CZ) – Vienna (AT)** approximately 224 km, has been equipped with a new type of CLA optical amplifiers CLA PB02 and started in mid 2006 year. Contracting and building of this CBF was more difficult and spent time with discussing and working on it was longer in comparison with other lines. CESNET has contracted the whole line and is covering all expenses. Brno – Vienna is consists of three parts of dark fibres from two providers. It was necessary to negotiate with two providers and to arrange connection of three segments. To use one master provider subcontracting others was not possible for commercial reasons. Problems were with determination and negotiation of right connect place and with measurement of the whole line (one fibre provider was not prepared for long NIL solution from management and technical point of views). CESNET is monitoring the whole line. The line is used mostly for IP connection 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 creating the first cross border dark fibre triangle. More details can be found at [17].

In summary, procurement, contracting and monitoring of CBF can be more difficult than leasing in single domain, however are very important for improvement of NREN services and very cost effective. High level of traffic on CBFs can be seen on [9].

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

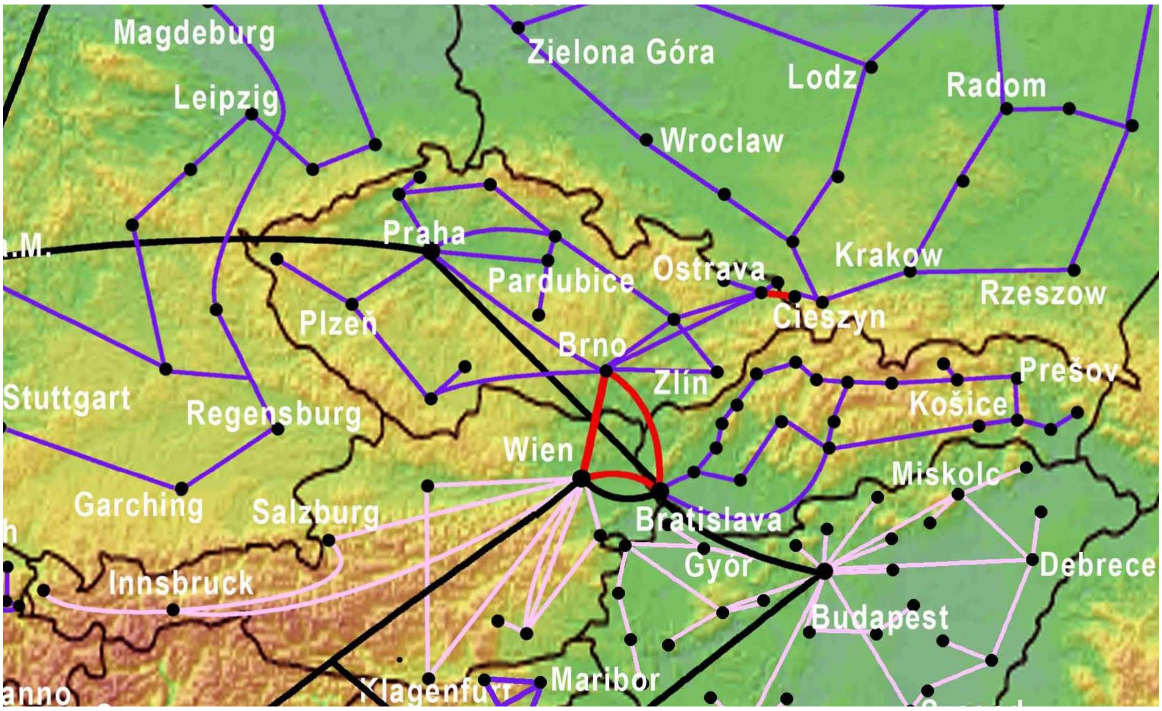


Figure 3.1: The first cross border dark fibre triangle

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

A dark fibre line between Subotica and Szeged has been established during 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.

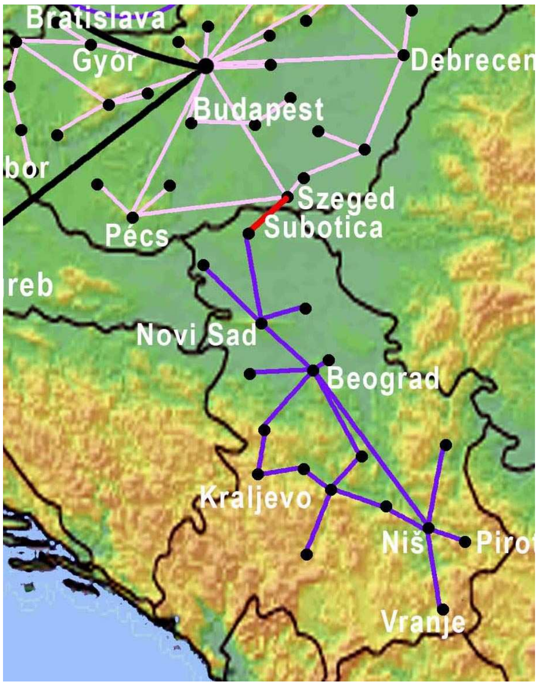


Figure 3.2: Cross border dark fibre connection Subotica – Szeged

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

GEANT2 lambdas over NRENs CBFs

GÉANT started dark fibre use since 2005. GÉANT2 network uses dark fibre connection of GÉANT PoPs located in NREN central PoPs (usually in Capitals). All GÉANT2 dark fibres are crossing borders with fibre lengths about 110 – 2000 km, but are not called CBFs (CBF should be short connection between neighbour NREN PoPs close to border). GÉANT2 dark fibre footprint is overlaying national dark fibre footprints.

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

Motivation:

- Installing of cost-effective lambdas to GÉANT2 PoPs for which are not available GÉANT2 dark fibres (for example Poznan)
- 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

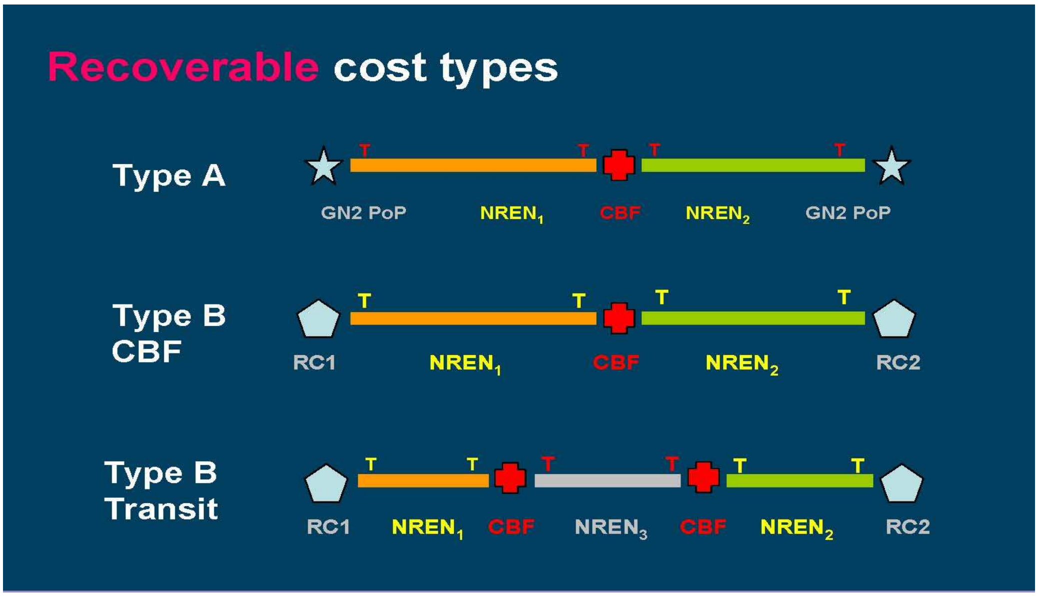


Figure 3.4: Recoverable cost types supported by GN2 project

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 connection 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)

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

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 covers fibre maintenance often. Taxation usually does not require separation of lease cost and maintenance cost, if both are paid recursively.

Monitoring by provider staff

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

Building of missing last miles

The bottleneck in providing high speed E2E services is last mile. Acquiring and contracting of building of last mile is very important part of tendering process. Not each of DF providers has possibility to offer fibres to demanded location, including subcontracting with metropolitan providers. There are more possible last mile solutions. Provider builds missing part of fibre line or deliver cheaper last mile on microwave technology in short time. Constructing of the line with using microwave or free space optics last mile for interim period up to building all dark fibre line is good solution sometimes. Typical price of laying dark fibre cable for one last mile km is about 41.700 Euro. For the first comparison: one microwave span 10Mb/s costs about 338 Euro, 34Mb/s costs 1.190 Euro, 100Mb/s costs 1.390 Euro and span lengths can be up to about 40 km, but direct visibility is needed.

CESNET acquired one provider capable of building last dark fibre lines and contracted building and the 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 right of use of optical fibres in last mile based on setup fee (installation) payment. “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 setup fee increases with number of fibres slowly and availability of fibres between university premises or NREN PoP to some near fibre meeting point is very important. Another reason for building of last mile fibre cables is to have fibre lines physical diversity to one PoP or premise for improvement of reliability (fibre outages like cuts cannot be sometimes repaired quickly and penalization is not able to solve such issue).

Tender and contract documentations

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

CESNET uses two another 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, is difficult to compare offers of fibre lease with offers of lambda service, if you are not sure (as usual) how many lambdas will be needed in contract duration. In such case, CESNET presumes 6 lambdas in call 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 ownership of fiber infrastructure. Below are briefly described several models of building fiber network taking into account PIONIER experience:

a) Fibres in common cable with other operator

Based on agreement PIONIER consortium purchased several fibres in cable of other provider. Agreement defines responsibilities and terms of use of the infrastructure. PIONIER is incurring costs of maintenance, operation and failure recovery. 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 fiber owner, in separate racks with independent power supply. According to the agreement with other provider PIONIER workers has unlimited access to this transmission equipment.

b) Own cable installed on high-voltage power lines

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

c) Own cable built along railways

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

d) Own fibre infrastructure built together with other operator

To limit cost of building of own fibre infrastructure investment was carried on together with other operator who also needed fibres along the same route. According to the agreement such 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. 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

At 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 diversity at the target countries leading to a specific contractual method. In all cases maintenance services are included at the DF acquisition contract and in most cases contract duration is for a long term period.

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

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

But NRENs are in a little different situation than “telco” operators, for them regular transport WDM network is not an objective but only a way how to transport more data.

Traditional approach (e.g. inline amplification and chromatic dispersion compensation each 80km) is not every time necessary. In principle transmission equipment just 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.

NRENs present very small market than that well established transmission equipment vendors have special NREN suitable series. Current typical approach is to deploy and use that equipment though some NREN useful features are not present and some features are there unnecessary. The worst is situation of full dependence on vendor’s research end design life cycles which is partially in contradiction of principles of research networking.

Interesting message is, that some traditional vendors start discussion about steps needed to offer “software programmability and flexibility required by the research community”, see [18]. It can be helpful, supposing NREN will continuously keep their independent lighting possibilities important from cost level and competition point of view.

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 to deliver the best possible services and features to R&E community without usage the newest and the most advanced technologies is difficult. A possibility of usage and deployment of the advanced photonics industry products is one of important drivers for photonic design kits. The idea is also supported by increasing presence of digital interfaces at optronic modules, though majority of optronic functions are analog based.

Absolutely essential issue of optical transmission is attenuation which can be overcome via optical amplification. Then the first choice is obviously design kit of optical amplifier. Concerning amplification it is possible to use different approaches, nevertheless usage of EDFAs (Erbium Doped Fibre Amplifier) and Raman amplification is the most common. EDFA technology was very well mastered in past and now EDFAs offers high reliability, high gain and reasonable low NF (Noise Figure). One drawback is quite limited spectral usability of EDFAs. This issue can handle Raman amplifiers, introducing broad spectral usability, very low NF but lower gain and potential presence of high power signals in transmission fibre.

Once transmission speed has grown to 10Gbps, necessity to handle CD (chromatic dispersion) appears. Traditional approach is usage of DCF (Dispersion Compensating Fiber), which is unfortunately quite bulky and lossy. Next approach to CD compensation is presented by use of FBG (Fiber Bragg Grating) which introduces lower losses and in special configuration also tuneability. As transmission speeds and powers (caused by many channel and large distances) in fibre grows a tolerance of receivers to CD falls and brings necessity of exact CD compensation.

4.3 Devices developed by CESNET

Already mentioned reasons led CESNET to develop own photonics design kits.

Amplifier kits called CLAs (CzechLight Amplifier)s have allow CESNET to apply and develop NIL (Nothing In Line) approach easily with remote control and management. CLA devices allow easily house up to 4 amplifiers in 1U case and benefit from the best amplifier modules available on market and reach very low NF and thus longer overcome 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 in general. This fact led CESNET to develop design kit of dual tunable CD compensator using FBGs. Device was designed both laboratory and field usable with remote control and management available.

Next tunable CD compensator, using different technology is also considered. It should offer price effective solution for NIL links without 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 the best known to authors including consideration both passive and active (amplified) technology. For 1GE both CWDM and DWDM technologies were considered. At first the NIL (Nothing in Line) solution costs are shown and after that 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)

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

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 very suitable place for deployment of NIL solution especially supported by photonic design kits. In fact CBF typically represent a demarcation between two domains - NRENs. 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. An effectiveness of this approach is indicated e.g. by deployment and operation of AT-CZ-SK CBF triangle allowing also resilience to one edge failure. More details can be found in [17]. Very cost-effective application is also using of CBFs to commodity Internet access.

Some CBFs are used also for implementation of lambdas connecting GÉANT2 PoPs or GÉANT2 PoP and premise important for some application project in neighbour county. CESNET and PSNC participate on pilot deployments and experiences are available to POS target countries.

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

At this section indicative prices are provided for optical transmission equipment which is available by traditional vendors of network equipment. This is estimation of POS experts based on offers received by that traditional vendors in procurements in last months. Prices do not include network management software and licenses, installation services and maintenance. It must be pointed that 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 follow:

- 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 occurs at the intermediate node but only amplification.
- 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 from proper link selection obviously. Keep-It-Short (KIS) approach plays extremely important role reducing quantity and complexity of equipment needed and thus both CAPEX and OPEX. However offers of fibre line routes and fibres are sometimes very limited and some rescheduling and re-tendering can bring new advantages. Concerning transmission equipment unfortunately we have to note that traditional approach plays important role still. Systems are still designed in one-fit-all manner predominantly. As mentioned above in traditional approach amplification and chromatic dispersion compensation using compensation fibre is done periodically each 80km. A 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 shortest distances (≈140 km for 1G) can be handled very easily in 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 important role for CBF links. Longer multi-hop links can also gain from usage of low-loss CD compensating devices allowing thus longer spans lengths like 120 or 100km. Tailored designs new photonic industry products can bring to NREN additional advantages as better and deep understanding of design principles, more experiences and thus advantages 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 prices from procurements for some NRENs (i.e. not list prices) in previous tables – see table 4.6. From discussion above should be clear, that values are not valid in some circumstances – differences can be even higher or smaller. For longer lines would be general comparison very large – there are many design alternatives. In these cases, analysis of real tasks is preferred. Column for 4x100km indicates that cost effectiveness open photonic design is not limited to NIL distances.

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

- Technology development road maps are not supporting needs of research networks adequately (it is small segment of 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 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)

Experiences show, that photonic devices are very stable and user usually needs support in design phase only.

Important and reliable results coming from table 4.6 are at least following:

- Every good design of lighting should take into account both possibilities now (traditional vendors and photonics vendors)
- For given fibre line or fibre footprint (having ready measurement of e2e 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)

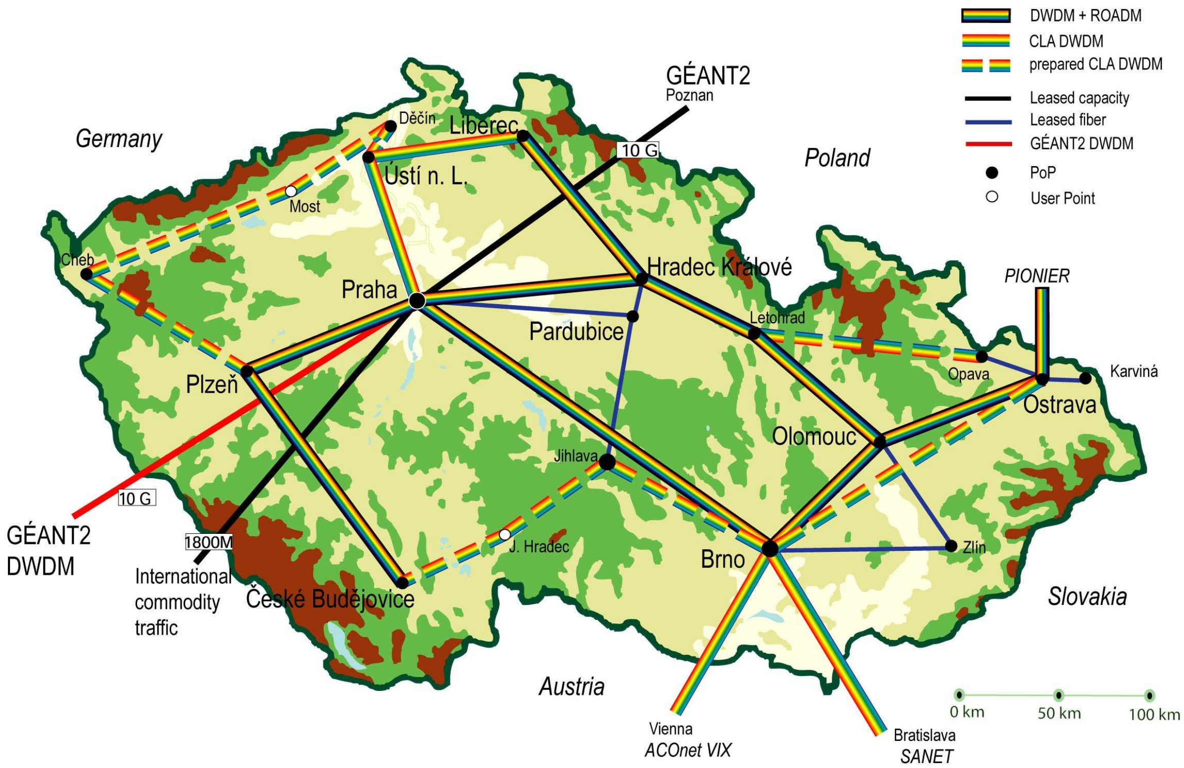


Figure 4.1: Mixed DWDM lighting in CESNET2 network and CBFs in June 2007

Deployment of photonics 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. Example of that solution called sometimes "mixed lighting" is in Fig. 4.1

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

Another important recommendation for future NREN budgets is coming from comparison of lighting cost tables for single fibre transmission and fibre pair transmission, taking into account cost of single fibre leasing or owning – see 5.3.

5 Fibre network cost model

5.1 Overall NREN budget per year

This Chapter 5 describes and discusses fibre network cost model based on **annualized** overall network costs.

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

Corresponding cost category in overall NREN budget is **transmission cost** as summary 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 transmission cost:

- Transmission capacity cost

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

It is also over 70% of overall NREN budget, if no costs for research are planned (see paragraph below). This means transmission costs are item needed main attention in economical analysis.

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

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

We will discuss that item in this Chapter 5. On the contrary to transmission cost, costs in this chapter are more difficult to estimate and compare in general - it depends more on time of equipment purchase, on using of multi-vendor approach, expected grow of network users and traffic, labour cost in given country, intent of NREN to participate in research, etc. Fortunately, that items are not so crucial for budget proposal, supposing 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 estimation for own country for years 2007-2010, based on discussion with POS partners.

Calculation of annualized costs allows cost comparison of different solution and designs and can be seen as similar to transformation to common denominator. We need to divide overall costs of item by supposed use time, so one of key input parameters are estimated (or planned) use time of owned fibres, equipment, etc. In general, use time can be different that 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). Partially similar situation is, if one time setup costs are paid in fibre lease contracts for indefinite period of time: use time of fibre need to be estimated for costs annualization. Fibre life time is usually also longer than IRU contract period (IRU provider limits own risk or fibre is not new in time of contracting, etc.).

Our colleagues without experience in accounting and economics can see annualized costs intuitively as cost of resources used (consumed) in 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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

Cost of fibre and cost on transmission equipment should are related mostly to distances. Cost of routing and switching equipment depends mostly on 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 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. Usual values are between 0.1 and 1 E/m/y, depending on conditions (see discussion in Chapter 3). Fibre footprint should be rather short ring(s) and preferred routes will be realized by implementing lambdas over this footprint.

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
T o t a l							

Table 5.2: Fibre budget table

Annotations:

Use time is duration of usage expected by NREN, if contract is made for an indefinite period of time or if NREN will be owner, or duration given by contract, if 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)	Use 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 annualized cost of fibre lighting. Decisions about dependency on single vendor of equipment or insisting on multi-vendor solution, using of advanced photonics lighting devices etc. (see Chapter 4) have strong impact on NREN 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 summa of fibre cost per year and meter and lighting cost per year and meter. This is **the most important indicator of network effectiveness**, because transmission costs in total are usually over 70% of budget for network operation.

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)
Total											

Table 5.3: Lighting and transmission budget table

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. If moving of some transmission to dark fibres is supposed in period 2008-2010, all budget tables for given NREN will be new starting for the year when movement is supposed (i.e. for the second or third phases of development), or description of step-wise changes will be done.

Depending on local telecommunication market situation, 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 indicator important for comparison with the same indicator in Table 5.3.

PoP A	PoP B	Distance on road (km)	Use 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

Annotations:

Service types can be:

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, implementation of service on first mile(s) should be indicated too, for example fibre, microwave, or free space laser.

5.1.4 Annualized cost of equipment in PoPs

Annualize costs of equipment for PoPs are item depending on type of service required. For beneficiary countries 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 few years. During use time of equipment, their replacement by new one and movement of old to new edge positions is possible, if necessary. Moreover, many items in equipment costs are still falling down. We can see advanced NRENs, where simple GE and 10GE switches in PoPs were sufficient for relatively long time (for example SANET) and supposed improvement trajectory is GE-10GE-100GE.

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

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)
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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

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 given type. Collocation cost in universities is usually about 5% of annualized equipment cost

R&SE&M cost: R&SE annual costs plus maintenance cost, usually about 10% of R&SE but higher for faster removing troubles of provider's network equipment

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 network. These costs are so significant we should not leave it out.

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

In following example we have 7895 kEUR as total of network operation costs (items 1, 2 and 3 of Table 5.1). Item 3 is total of Other network operation cost 1395 kEUR for network with about 5.000 km dark fibre separated into 42 lines connecting 20 NREN PoPs. Person Month (PM) costs are about 2000 Euro/month. Fibre maintenance and in-line equipment annualized costs and collocation cost are included in item 1, as well as equipment maintenance cost about 430 kE/y and PoP equipment collocation costs 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.)
3.6	Miscellaneous	79	-	Occasional services, SW (non-CAPEX) and other costs.
	TOTAL of Operation	**7 895**	**100%**	Item 1,2 and 3 (Annualized cost of fibre plus annualized lighting costs plus annualized cost of routing and

	(1-3 items)			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 example above and in 5.2. If better estimation is not available, we can take item 3 as 20% of sum Item 1 plus Item 2.

5.1.6 Research of advanced networking

Network operation costs analyzed above do not contain resources for improvement of networking. This means one part of general NREN mission is missing 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 are contributing to this world-wide mission. One of reasons can be that networking research is traditionally done in universities, research institutes or supercomputing centres in given country. New NRENs and NRENs during their first stage of their evolution are usually orientated only to provide basic network services. We could say, that top level research of networking is not necessary to do in each country (in contrary to deployment of its results), but there are reasons against such 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 given country largely depends on participation of local researchers
- high quality of education depends on participation on top level research
- EU supports international research projects and participation of national resources is needed.

In the table below you can see an example what part of NREN annual budget is used for research of networking and what part of staff work load is oriented to research of networking.

	Research of networking	**Network operation**
% of total budget	42%	58%
% of total work load	73%	27%

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

Especially costs of equipment and fibre lease make the network operation budget major. There is high synergy in doing network operation and research of networking in one subject (i.e. separation would be very expensive). Especially development of 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 suppose for future research cooperation with beneficiary countries NRENs.

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

Involving in research of networking (or more generally in research and development, R&D) you can see for example in CESNET, GRNET, SURFNET, PSNC with positive effects:

- More value added for the same costs:
  Results of the R&D allow to develop current or implementing new services of the NREN for the approximately the constant level of the costs for network providing. It means, the efficiency of the services including network providing is higher and more value added for the same costs is the effect for all users of the NREN services. The development of the services by the way of purchases from suppliers would by more expensive.
- Better efficiency of the R&D
  Majority of employee working in R&D is part time staff. They are often common employee of some universities etc. Actually these NRENs became an organization of cooperation of networking oriented employee of the universities and academies of sciences, concentrated brains and sources, which giving more efficiency and opportunities for all participants and investors, especially at the case of the smaller states.
- Contribution to an education system, telecommunication branch and economy
  This mission allows networking orientated scientist better to involve in projects with international stature and outcomes. Acquired know-how is brought to education system and through the graduates then to business, which has the positive contributions for the telecommunication branch at all and it`s users. This business purveys infrastructure for the other branches, so it is possible to observe, high-quality R&D brings contributions to the whole economy. High-quality R&D allows better to reach the goals of EU and member states to increase technological level, which the EU Research Framework or other national programs go after.

5.1.7 Cost of front payment

Comparison of costs should distinguish between monthly payments and payments in advance (front payments), if we need to compare annualized costs and understand, what offer are more cost effective. If installation fee, first mile building fee, purchase fee, other One Time Charge (OTC) or whatever Non-Recurring Charges (NRC) are used, you should divide this fee by use time and add the result into one year cost. Moreover, you should add interest available to you, if rest of NRC value used temporarily as bank deposit before using for Recurring Monthly Charges (RMC). This means time value of NRC instead of value of NRC should be used in tables. (If repeated payments in advance are requested, you should evaluate time value of each that 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

By double click on this table you can do calculation for different input values. It can be seen, that even for small values of expected average interest is using of time value of NRC instead of 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.

Example of calculation, whether advanced payment has advantage to user, is following:

Contract period (year)	Advanced 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: advanced 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.)

5.2 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 with more or less guaranty of interoperability. Network design is supposed to be done by using this kit (sometime they speaks about configuration rather then design).

Nearly all long term working NRENs are using routing and switching equipment from traditional vendors, because other possibilities are relatively new. We will use PIONIER network as case study for annualized cost analysis, because data are publicly available. For simplicity, we 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 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 lines where 1G transmission is leased. Switches bought from the same manufacturer are localized in each PIONIER PoP. Two routers are localized in PSNC premises in Poznan. One of these routers plays backup role. In order to have an access to every kind of network or power system devices management system “out-of-band” using GPRS / EDGE technology was installed in each PoP and amplifying node.

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

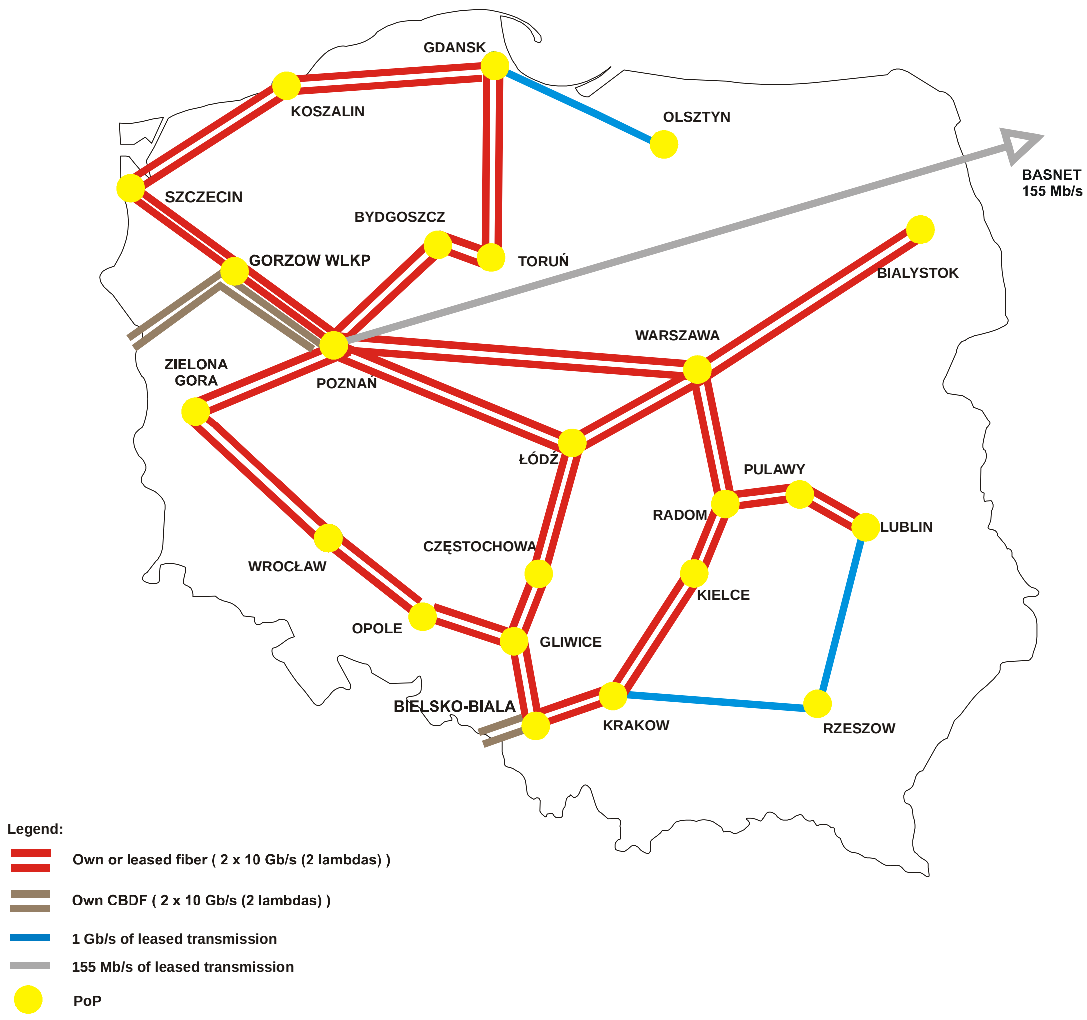


Figure 5.1: PIONIER network infrastructure in May 2007.

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

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	
Total		**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
Total		**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	
Total		**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**
Total	**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 needs to upgrade services for network users communities in connected metropolitan area networks (MAN) and upgrade 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 example for the future upgrade of networks in beneficiary countries, but prices is expected to fall down in the future.

5.3 Cost effectiveness of single fibre transmission

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

- if cost of single fibre line is lower than cost of fibre pair (it depends on provider offers), is necessary to compare costs of both single and pair solutions (annualized cost difference of fibres usually prevails annualized cost difference in lighting) – annualized total cost difference can be about 40% and transmission costs is usually the biggest item of NREN budget
- NREN owning or building fibres can decide about single fibre transmission simply, free fibres can be swapped
- 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 optical point of view single fibre bidirectional transmission differs from fibre pair transmission in presence of some passive components, which splitting directions only. Thus reliability of single fibre transmission devices is very similar to fibre pair transmission devices. Number of providers offering single fibre lease is increasing. Typical cost of single fibre lease is 60% of fibre pair lease, so it can be interesting for providers. NRENs building fibres have even better position. CESNET experience shows no problems with single fibre transmission since 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]. Method for cost-effective usage of fibre pair for single fibre transmission was developed in SWITCH: In one fibre long haul back bone traffic is bi-directionally carried, second one 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.

To give example, we can calculate fibre budget table and lighting budget tables for 200 km fibre (single or pair) and for 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)	Use 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)	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)
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)	Comparison 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

Resulting cost difference in Table 4.9 is 44% respective 48% of transmission costs - very good reason to study this issue and taken 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 not supports single fibre transmission, we should see his lighting product portfolio incomplete.

5.4 Cost of routing and switching equipment - open photonics design

In this subchapter we discuss possibilities given by insisting on interoperability of devices and equipment of different vendors in procurement and contracting time, guaranteed of course also by field testing of interoperability and performance. Equipment of photonic vendors (especially transceivers) is used as well as routers or switches of some traditional vendors.

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

For this presented example, three different traditional vendors have been chosen to illustrate possible price differences. It's advisable that a modern Point of Presence (PoP) should offer 1 GE and even 10 GE interfaces to support requests 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 presented 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 requests for 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 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 use of pluggable optical transceivers (GBIC and SFP for 1 GE, XENPAK and XFP for 10 GE). These transceivers give freedom to choose the right type for every application (i.e. multimode or single mode fibres, for distances from few metres up to 80 kilometres without amplification). A new DWDM version of pluggable transceivers are available now which allow for low cost DWDM transmission by use of 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 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 and to have appropriate agreement about acceptation of third party products in purchase contract.**

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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

As the final word it can be stressed that all numbers presented here are examples based on CESNET practical experiences and it should not be surprising to obtain other prices 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's 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 own routing equipment, which is not managed and therefore not paid by SURFnet.

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

Any network will need one (or two for redundancy) so called border router (not in a geographical sense) which is capable to handle, for example, full Internet routing tables. The price of this border router will be significantly higher then 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 big number of 10 G ports and supporting most advanced features. Some re-estimation can be done and for not so big number of 10 G ports, the price of a border router can be from 100 000 euros to 150 000 euros.

But it is not necessary to deploy so expensive equipment in all PoPs and for budgetary purposes for the rest of a network, prices from Table 5.1 can be used . For example, Vendor B can be chosen as a 'middle course' example. The differences in prices may seem confusing and perhaps irresponsible 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 example budget. The list of 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 example prices from Table 5.14.

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

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 design described in this Appendix can serve as an example for understanding of lighting issue 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 last few years in CESNET.

In addition to price information from Table 5.14, prices of other transmission equipment summarized in Table 5.15 are used for all budgetary calculations for example in chapter 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 is possible to buy from a manufacturer exactly the same transceiver as is usually delivered by traditional vendor (but price, etiquette and contract conditions differ).

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

6 Budget recommended for NRENs in beneficiary countries

Each beneficiary country had task to elaborate budget suggestion based on previous chapters, respective appendixes and on acquired information about fibre and service availability. Results have uniform structure as much as was possible in very different conditions. Consultation with CESNET, GRNET, PSNC or other partners was used very intensively by some beneficiary countries.

Budgets are based on prices supposed for NRENs by fibre or service providers, equipment vendors, etc. and discounts were subtracted at usual level for NRENs. If some value, row or table is missing in budget tables for given country comparing with Appendix A it means, that for given country is not needed or is zero. No budgetary reserve is added. Budgets are estimations what are necessary, based on today's knowledge.

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

Taking xxx as total value of NREN budget in the table, supposed national government (or funding agency) decision is in style: **"We allocate funding X kEuro per year for support of NREN. NREN is responsible for the best usage in the sense of POS project deliverables."** Similar situation should be in possible multi-source funding.

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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

6.1 Armenia

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

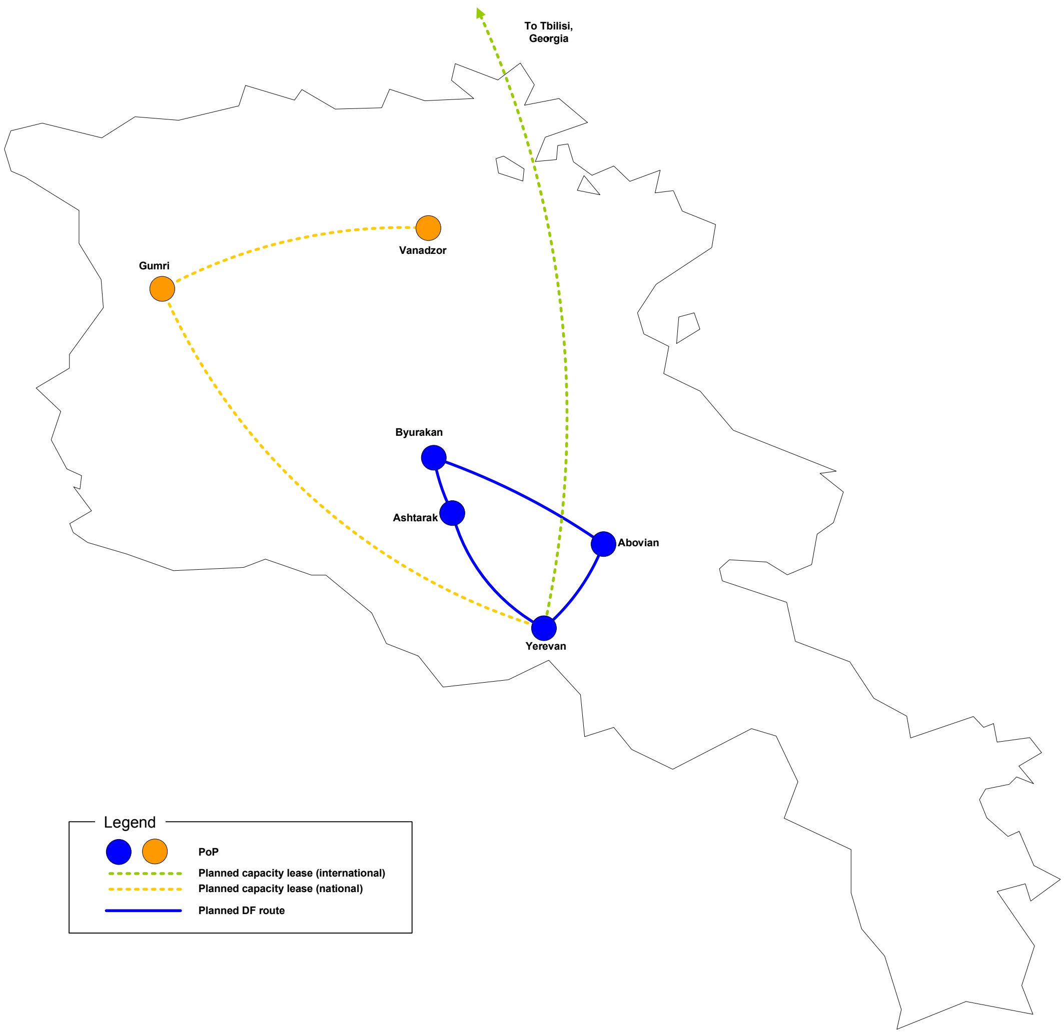


Figure 6.1: Phase 1 of fiber network development in Armenia

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	1,54	

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	0,96	2,50

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	5,51	

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

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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

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**	**0,38**	

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**	**0,04**	0,42

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**	**5,51**	

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**

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

6.2 Azerbaijan

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

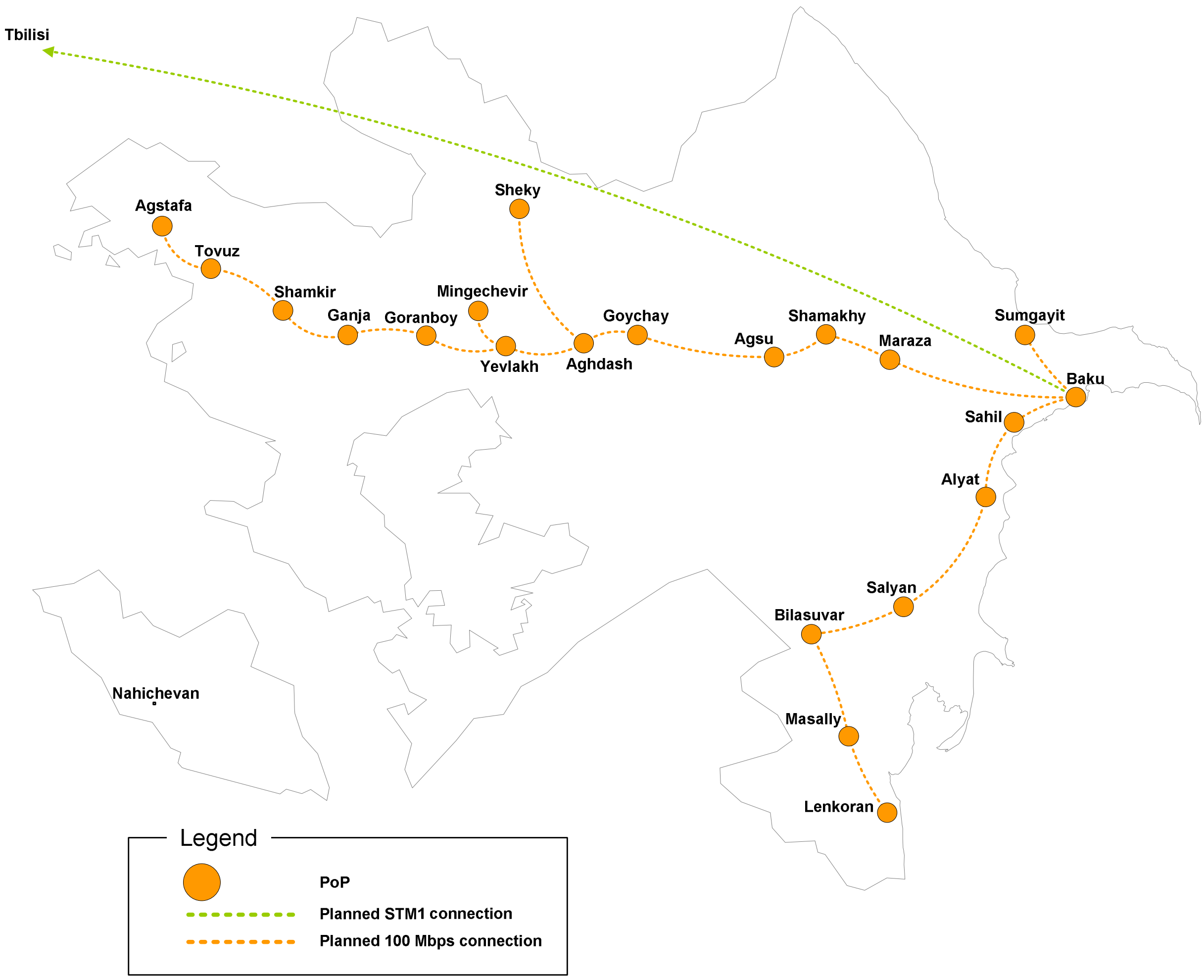


Figure 6.2. Azerbaijani NREN leased transmission capacity in the first phase.

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		**610**		**3 390,00**	**3 390,00**	**5,56**	

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:

- using of national infrastructure is received as government support

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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

6.3 Belarus

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

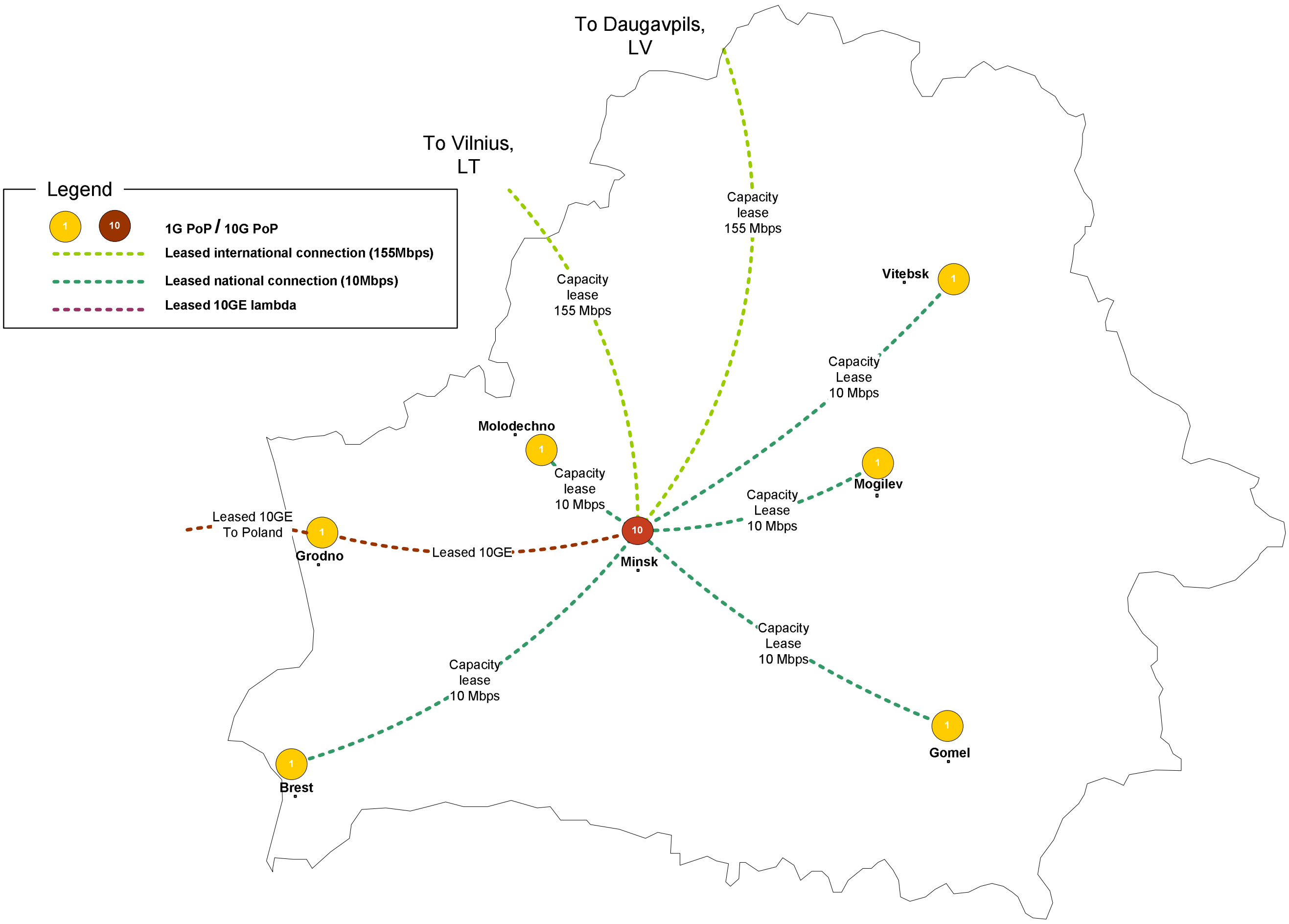


Figure 6.3. First phase of Belarussian research and education network development.

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**	**0,88**	

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**	**0,59**	**2,45**

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**	**9,88**	

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**

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

6.4 Estonia

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

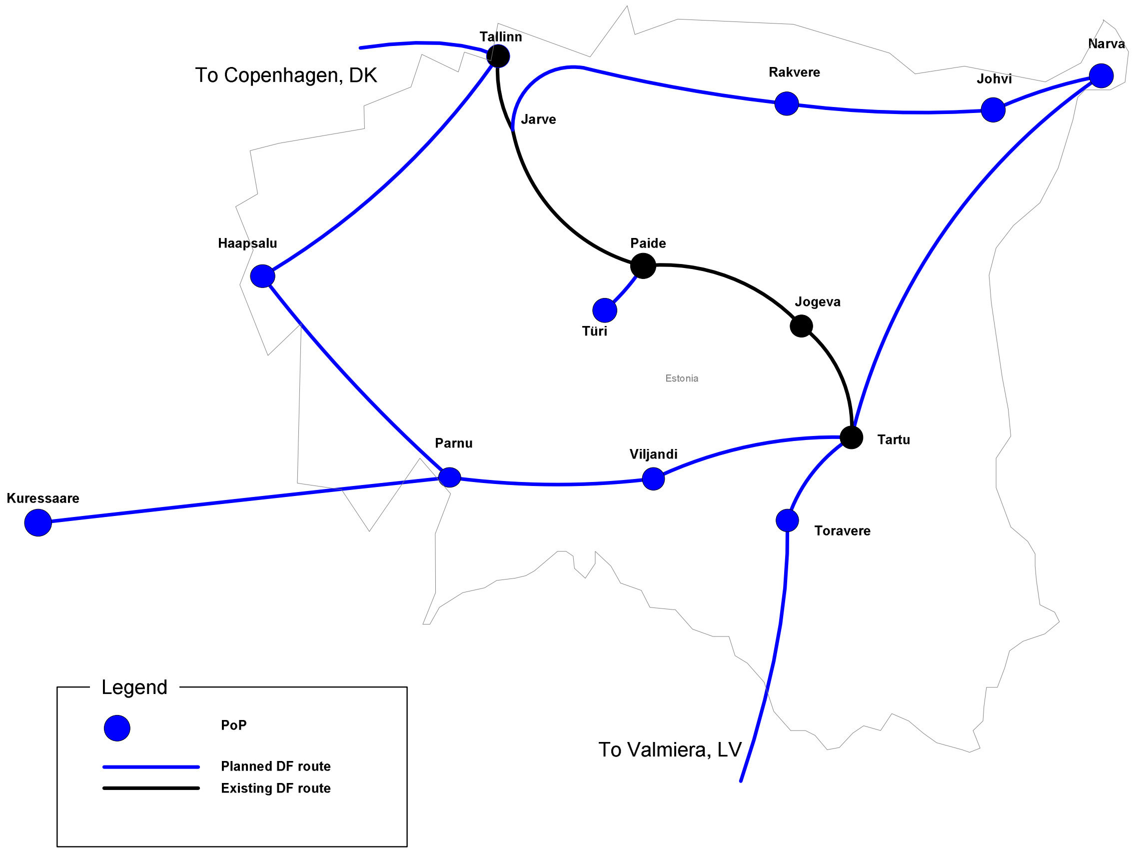


Figure 6.4. Estonian NREN existing and planned DF routes in the first phase.

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
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**	**0,56**	

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**	0,16	
Haapsalu	Pärnu	1	2	38,4	5	8	8		**8,45**	0,11	
Pärnu	Kuressaare	1	2	66,6	5	13	15		**14,65**	0,12	
Tartu	Toravere	3	1	163,2	5	33	36		**35,90**	0,18	
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**	**2,81**	

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**

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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

6.5 Georgia

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

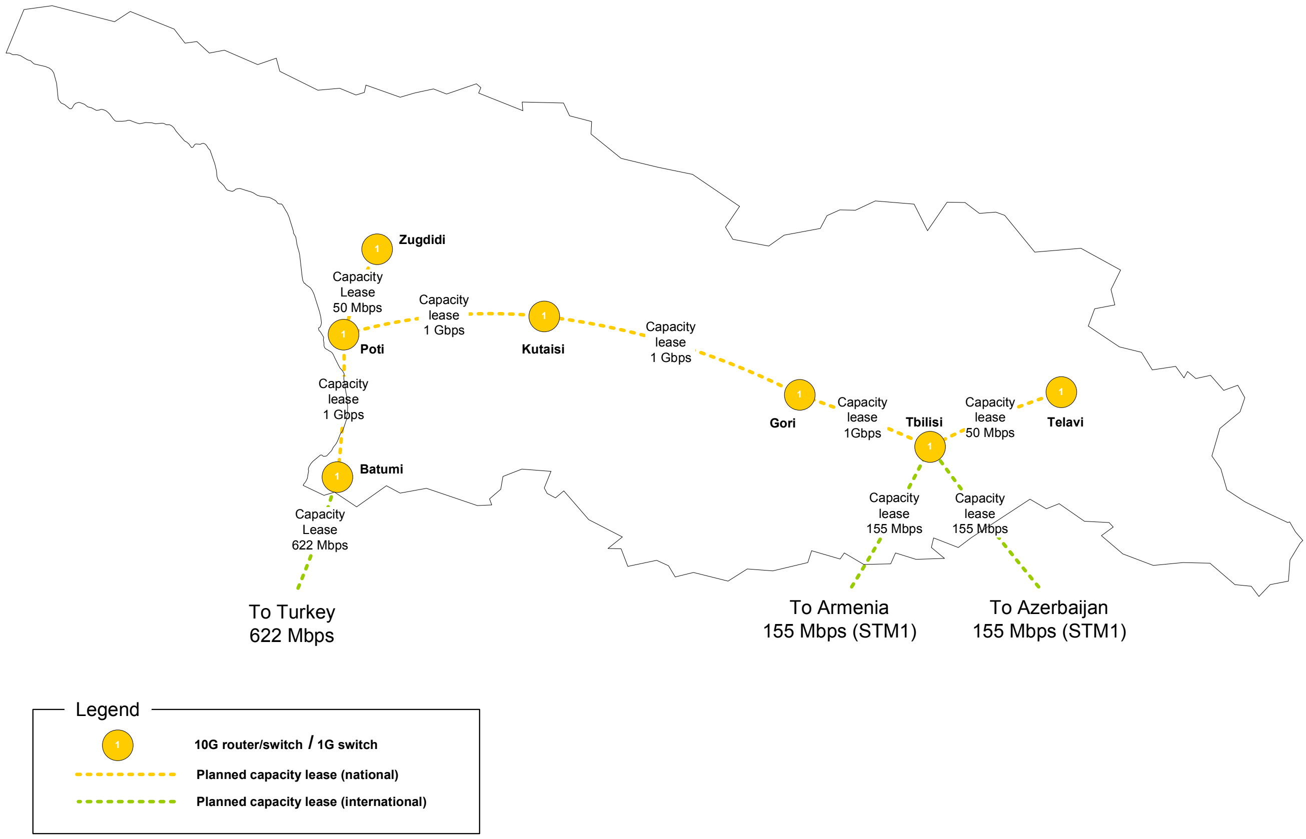


Figure 6.5. Georgian NREN leased transmission capacity in the first phase.

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	0,85	

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

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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

6.6 Latvia

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

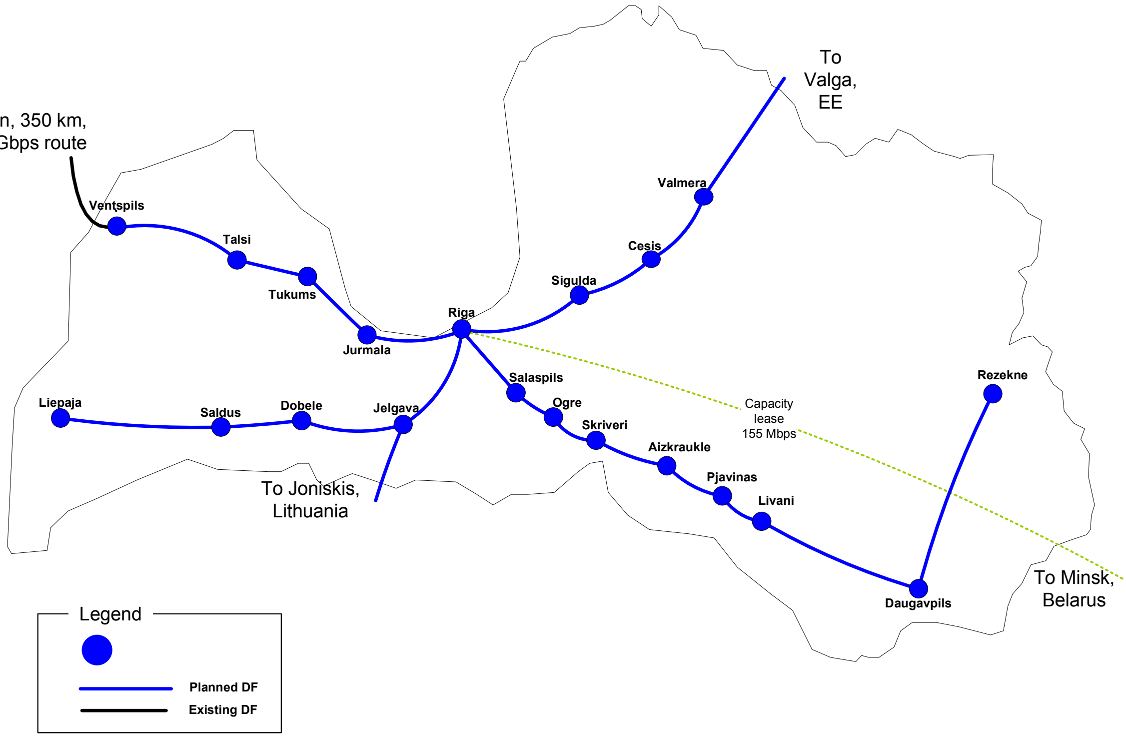


Figure 6.6. Phase 1 of fibre network development in Latvia

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**	**1,50**	

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 -Jonisk	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		**11**	**21**	**2 060**		**411,96**	**453,16**	**0,00**	**453,16**	**2,56**	**10,48**

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**	**201**	**480**		**96,00**	**105,60**	**4,80**	**110,40**

Overall NREN budget needed for successful network development in Latvia using traditional lighting is: **2 752 050 Euro 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
T o t a l		**1035**		**7 540**	**1 553**	**1,50**	

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
T o t a l		**11**	**21**	**349**		**112**	**123**	**0**	**123**	**0,72**	**2,22**

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
T o t a l		**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**
T o t a l	**21**	**201**	**480**		**96,00**	**105,60**	**4,80**	**110,40**

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

6.7 Lithuania

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

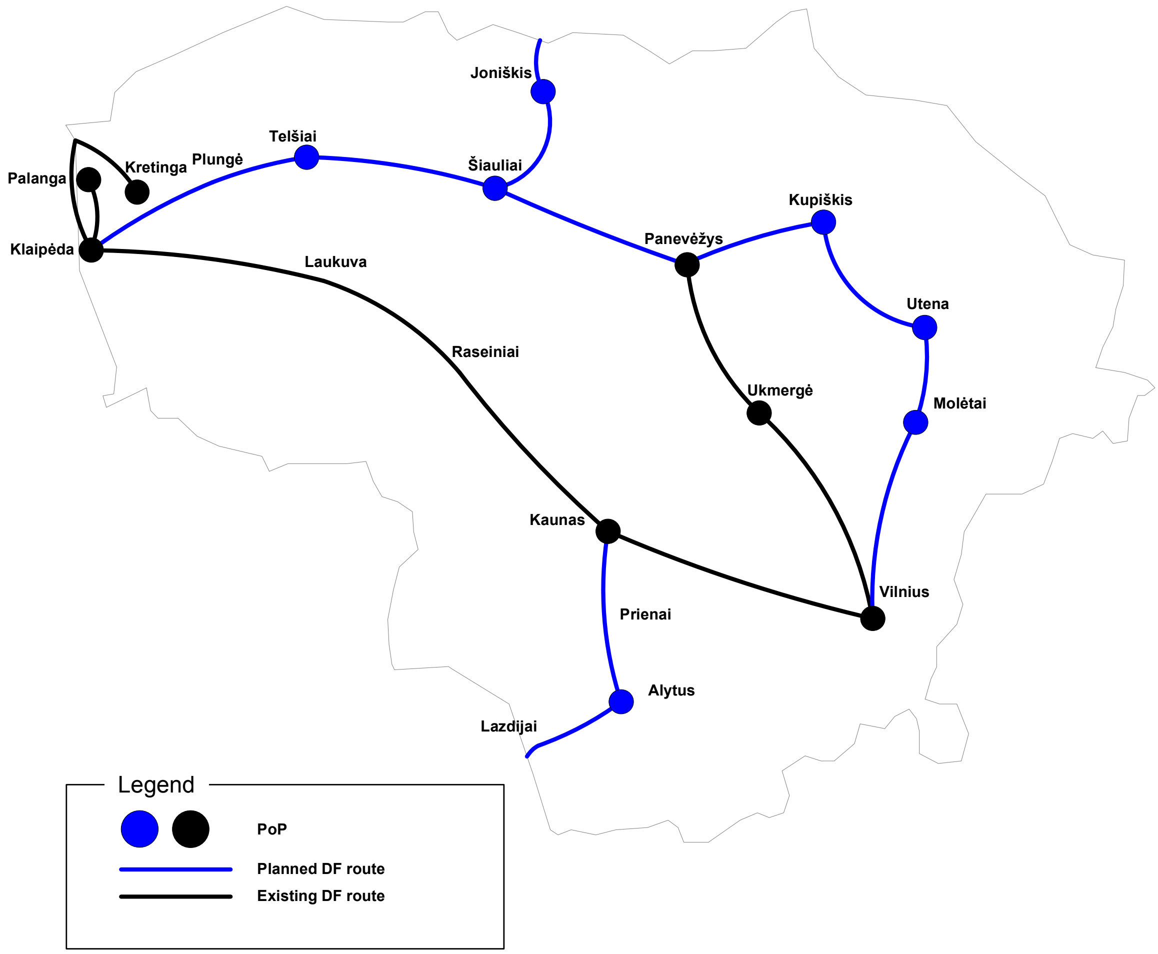


Figure 6.7. Lithuanian NREN existing and planned DF routes in the first phase.

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
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**	**0,39**	

Table of Overall NREN budget

Item	Cost Category	Annualized costs (kE/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

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	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**	**3,88**	**4,27**

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)
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**	**279**	**1127**		**112,70**	**123,97**	**5,64**	**129,61**

Overall NREN budget needed for successful network development in Lithuania using traditional lighting is: **1 064 460 Euro 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**	**0,39**	

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**	**1,09**	**1,48**

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

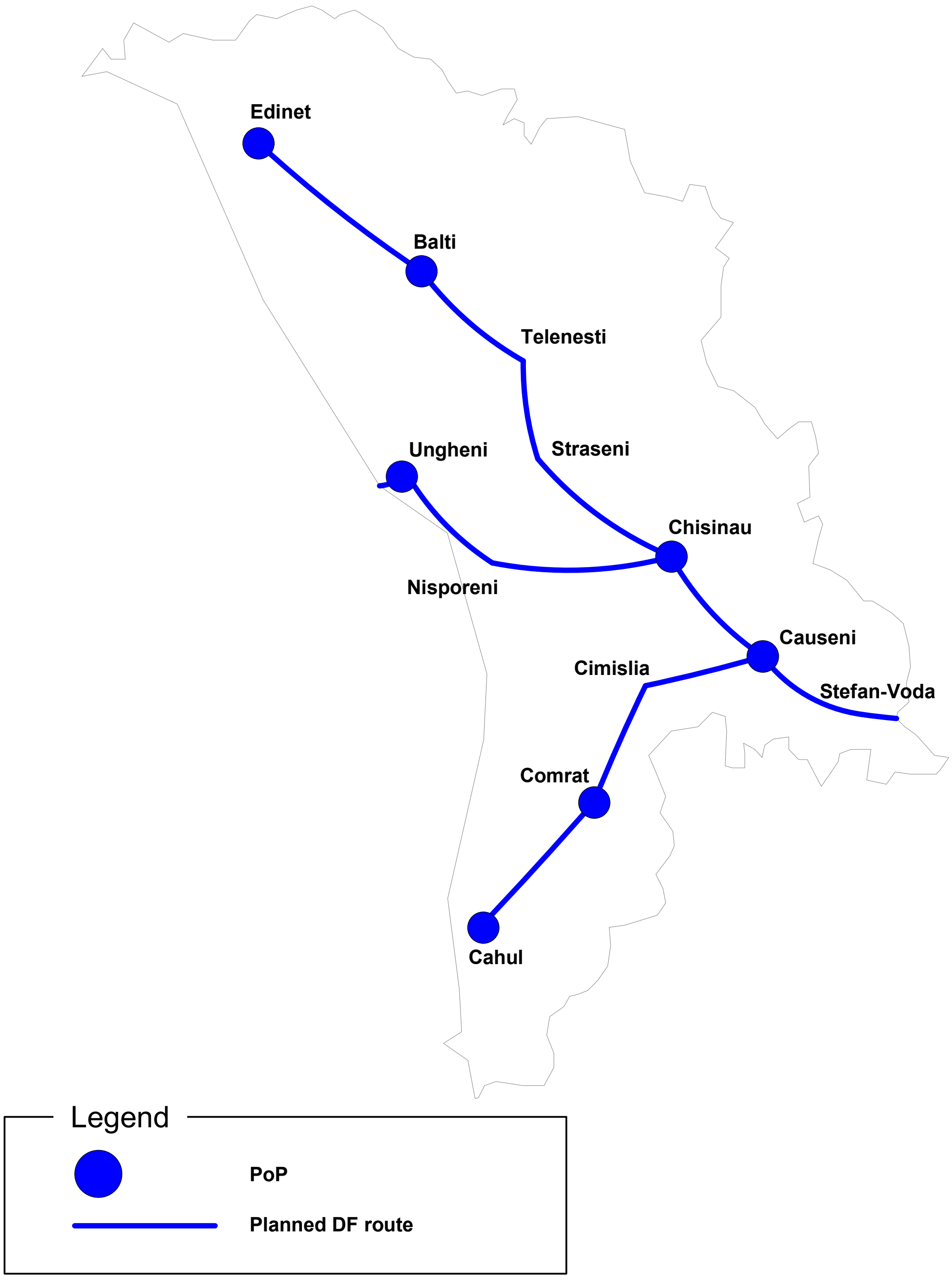
Type of PoP	Number of PoPs	R&SE cost per PoP (kE)	R&SE cost (kE)	Use time (year)	R&SE cost per year (kE/y)	R&SE&M cost (kE/y)	COLO cost (kE/y)	**PoP cost per year (kE/y)**
10G core	5	150	750	10	75,00	82,50	3,75	**86,25**
10G acce	1	23	23	10	2,30	2,53	0,12	**2,65**
1G core	3	100	300	10	30,00	33,00	1,50	**34,50**
1G acces	9	6	54	10	5,40	5,94	0,27	**6,21**
Total	**18**	**279**	**1127**		**112,70**	**123,97**	**5,64**	**129,61**

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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

6.8 Moldova

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



Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

Figure 6.8. Moldavian NREN 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
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**	**0,67**	

Table of Overall NREN budget

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**	**0,48**	**1,15**

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**

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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

Budget table 2: Dark fibre footprint, photonic lighting

Templates

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	constructio n
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**	**0,67**	

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**	**0,21**	**0,89**

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**

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

6.9 Ukraine

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

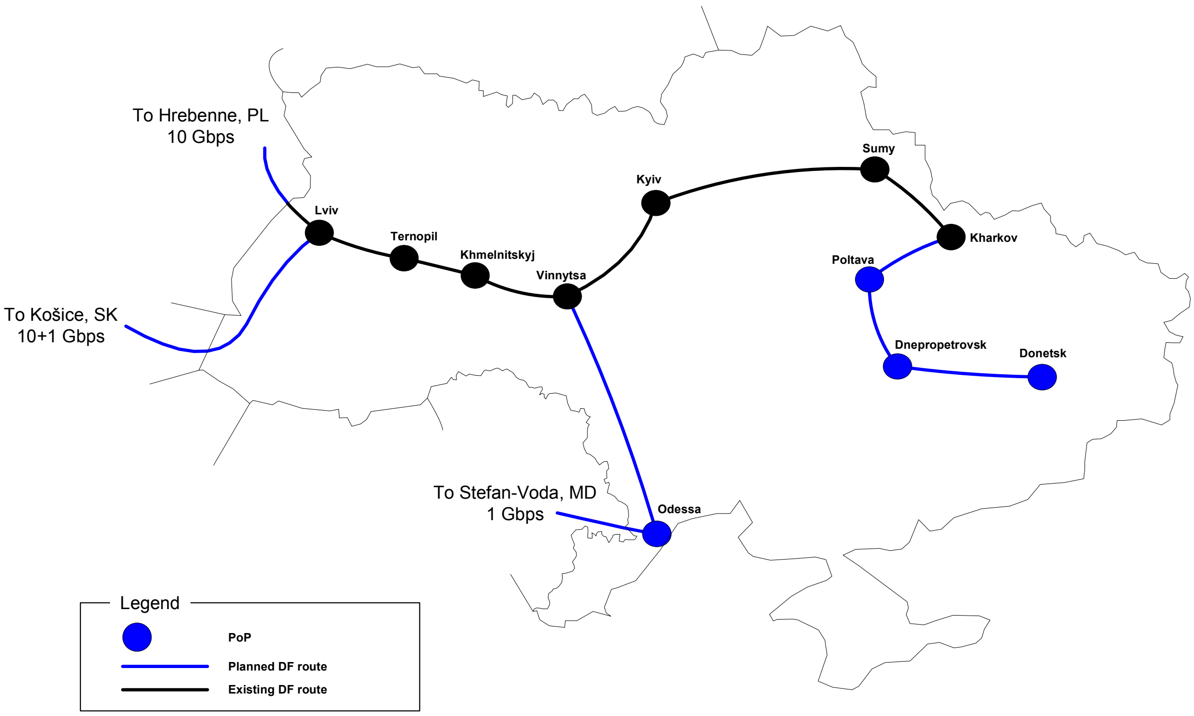


Figure 6.9. Ukrainian NREN existing and planned DF routes in the first phase

PORTA OPTICA

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**	0,30	

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**	**2,30**	**4,36**

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**

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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

7 Conclusion

There are main recommendations for EC, governments of target countries, GN2 project, and NRENs in these countries:

A. EU should take appropriate steps to support national funding of research and educational network development and operation in Armenia, Azerbaijan, Belarus, Estonia, Georgia, Latvia, Lithuania, Moldova and Ukraine, **considering budget recommendations in Chapter 6 of this deliverable.**

B. Governments of Armenia, Azerbaijan, Belarus, Estonia, Georgia, Latvia, Lithuania, Moldova and Ukraine should declare Research networks as enabler to equal participation in world-wide research and for participation in coming knowledge based economy and **improvement of overall country prosperity** (see [27])

C. GN2 project and prepared GN3 project should coordinate leasing of dark fibres crossing borders with NRENs using CBF connection for NRENs self-interconnections, access to NIXs and commodity Internet traffic. The goal is to avoid leasing of expensive parallel fibre lines in the future, if using of lambdas based on CBF self-interconnection is sufficient solution.

D. NRENs of Armenia, Azerbaijan, Belarus, Estonia, Georgia, Latvia, Lithuania, Moldova and Ukraine should support building of new optical cables or metropolitan fibre structures by expert knowledge and have deal in fibre allocation. World-wide collaboration of NRENs allows access to top level knowledge and experience in networking and this make such support very strong.

E. EU should take appropriate steps to support research of advanced networking technologies (including innovative new photonic technology, which substantially improve cost effectiveness) application in wide-area networks. In the first step it should be oriented to deployment of advanced programmable devices in suitable research and education networks in POS countries and in other countries. 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.

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

8 References

[1] Stanislav Sima: Experience with Cross Border Fibre connection in Europe and with advanced optical devices deployments, Porta Optica workshop Kiev, 2006

[2] SEEFIRE project, Deliverable D3.2: Economic Model for the Acquisition and Operation of Dark Fibre Networks in SE Europe: http://www.seefire.org/content/modules/downloads/SEEFIRE-WP3-Economic-study-d-20060223x.pdf

[3] SEEFIRE project, Deliverable D2.2 Support for Deployment of Customer Empowered Fibre Infrastructure http://www.seefire.org/content/modules/downloads/SEEFIRE-WP2-D2.2-GuidelinesfortheDeploymentofCEFInfrastructure%20-k%20-20060130.pdf

[4] Linda Ross: FiberCo/WaveCo Update, Joint Techs workshops, Minneapolis, February 12, 2007 http://www.internet2.edu/presentations/jt2007feb/20070212-roos.htm

[5] Jose Fernandes: Are Structural Funds a good option for funding fibre infrastructure? SEEFIRE Policy workshop, 2006, Bucharest, http://www.seefire.org/content/modules/downloads/09-Jose%20Fernandes-FCCN-Are%20Structural%20Funds%20a%20good%20option%20for%20funding.pdf

[6] Jorge Sanchez: Dark Fibre Opportunities in the region. SEEFIRE Policy workshop, 2006, Bucharest, http://www.seefire.org/content/modules/downloads/10-Jorge%20Sanchez-GRNET-DF%20Opportunities%20in%20SEE.pdf

[7] Figure: Using of DWDM pluggable transceivers http://www.cesnet.cz/doc/2006/zprava/xl-posn.gif in CESNET Annual research report (in Czech), Praha 2006, http://www.cesnet.cz/doc/2006/zprava/

[8] Porta Optica Study, Deliverable D2.2 Special issues related to Southern Caucasus http://www.porta-optica.org/files/publications/POS-D2.2_Special_issues_related_to_Southern_Caucasus.pdf

[9] CESNET2 load map http://www.cesnet.cz/provoz/zatizeni/ten155_mapa/mapa.last_month.20070400.html

[10] Porta Optica Study, Deliverable D1.2 NREN Status and Development Plans http://www.porta-optica.org/files/publications/POS-Deliverable1.2v1_NREN_status_and_development_plans.pdf

[11] Stanislav Sima: East European Leapfrogging, 4th International Workshop on Open Access, Stockholm, December 2006, http://www.wideopenaccess.net/2006/files/session2/sima.pdf

[12] Stanislav Sima: Open Photonic Devices in CEF Networks, http://www.thequilt.net/meetings/Apr-07-wksp/QUILT%20Stanislav.ppt

[13] Vaclav Novak, Josef Vojtech: Deployment of a DWDM System with CLA Optical Amplifiers in the CESNET2 Network. CESNET Technical report Praha 2006, http://www.cesnet.cz/doc/techzpravy/2006/dwdm-cla/dwdm-cla.pdf

[14] Lada Altmannova: Dark Fibres in European NRENs, http://www.thequilt.net/meetings/Apr-07-wksp/QUILT%20Lada.ppt

[15] 4th International Workshop on Open Access, Stockholm, December 2006, http://www.wideopenaccess.net/2006/

[17] Cross Border Dark Fibre triangle for multiple 10 gigabit connection of Austrian, Czech and Slovak research and education networks enabled by advanced photonic technology, common press release, http://www.ces.net/doc/press/2006/pr061106.html.

[18] Martin Nuss: Programmable Optical Networks: Enabling Research Networks to Adapt Lightpath Connectivity to Fit End User Requirements, Joint Techs workshops Internet2+ESnet, International conference of networking engineers, Mineapolis, 2007. http://www.internet2.edu/presentations/jt2007feb/20070212-nuss.pdf

[19] Felix Kugler: DWDMlight – lightweight optical links built from multi-vendor equipment. CEF Network Workshop, Prague 2006, http://www.ces.net/doc/seminars/20060529/pr/kugler.pdf

[20] Kees Neegers: GLIF Infrastructure. SC2004, Pittsburgh. http://www.glif.is/publications/presentations/20041112KN_SC04_glifpanel.ppt.

[21] List of references to photonic clusters, http://photonicsclusters.org/cluster-list.dxp

[22] Photonic clusters in U.S. *http://photonicsclusters.org/usamap.html*

[23] Photonic clusters in UK:. http://www.photonicscluster-uk.org/

[24] Hans Döbbeling: Cross Border Services within the GÉANT2 Project, CEF Network Workshop, Prague 2006, http://www.ces.net/doc/seminars/20060529/pr/doebbeling.pdf

[25] Viviane Reding, Member of the European Commission responsible for Information Society and Media: Strengthening Photonics Research in Europe. Official launch of PHOTONICS21 (European Photonics Platform) Brussels, 2 December 2005, http://ec.europa.eu/commission_barroso/reding/docs/speeches/photonics_20051202.pdf

[26] Alan Hollander: Optical Networking Innovations. CEF Network Workshop, Prague 2005, http://www.ces.net/doc/seminars/20050516/pr/hollander.pdf

[27] Robert D. Atkinson & Andrew S. Mckay: Digital Prosperity. Understanding the Economic Benefits of the Information Technology Revolution. The Information Technology and Innovation Foundation (ITIF), March 2007, http://www.itif.org/files/digital_prosperity.pdf

[28] Foundry NetIron XMR 8000 description: www.foundrynet.com/products/sp/int-route-core/ni-xmr.html

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

Following table group allow switch to Excel form by double click. Values describing projected network should be inserted to empty cells of tables and cells containing zeros are calculated immediately. 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 correctly situation of NREN, please use right coefficients or constants in adequate cells.

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 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.

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

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)
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

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)
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 Scenario2a

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)
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 Scenario2b

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)
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)	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)
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)	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)
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 Scenario2b

This examples show important possibilities of transmission system design 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 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 require advanced needs with 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 require 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 rest ie 11 cities may not require high-end equipment because it’s not that expensive.

The routes with NREN development preference 1:

1. Route **A** – **I** – J – K – **G** ie 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** ie 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** ie 8 spans, distance for this route would be ~ 350 km ie 44 km per span, 10 Gb/s.

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

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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

1 Scenario 1

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 like this:

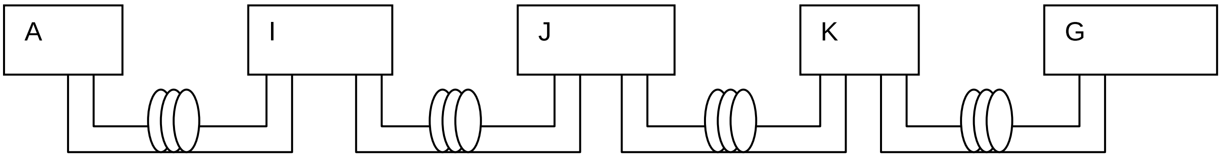


Figure B.1: Route 1 with 1550 nm 10 G transceivers, single channel

Only 10 G 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). But 10 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 10 G 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 this adds fees for housing of inline amplifiers somewhere along the line.

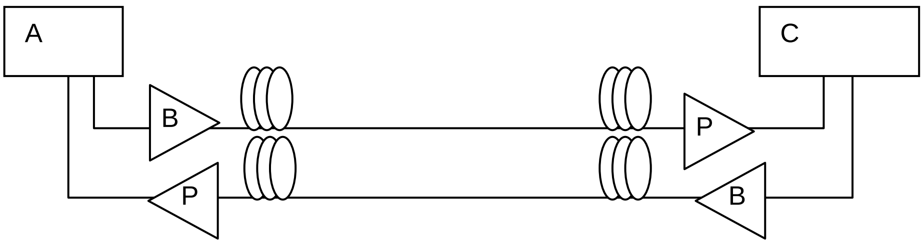


Figure B.2: Route 6, nothing in line solution with boosters and preamplifiers

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

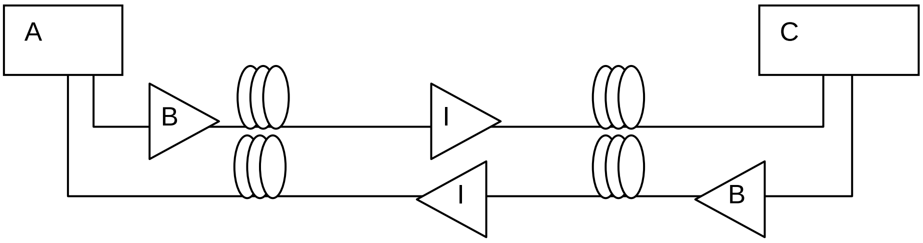


Figure B.3: Route 6, solution with inline amplifiers

2 Scenario 2

Here, 1 G or 10 G 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.

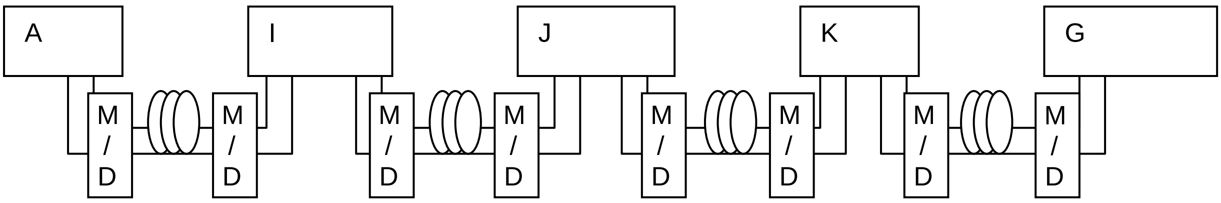


Figure B.4: Route 1 with DWDM 10 G transceivers and DWDM multiplexors and demultiplexors for Scenario 2a

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

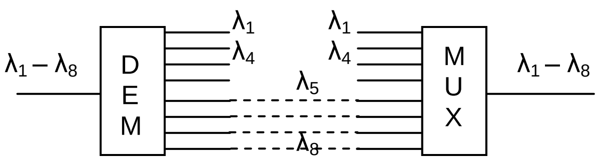


Figure B.5: A back to back configuration of a pair mux and demux: 4 lambdas (λ5 – λ8) are express and 4 lambdas (λ1 – λ4) are added/dropped

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.

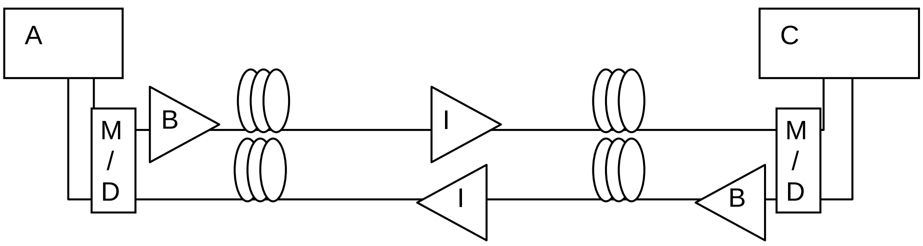


Figure B.6: Route 6, multichannel solution with inline amplifiers for Scenario 2a

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.

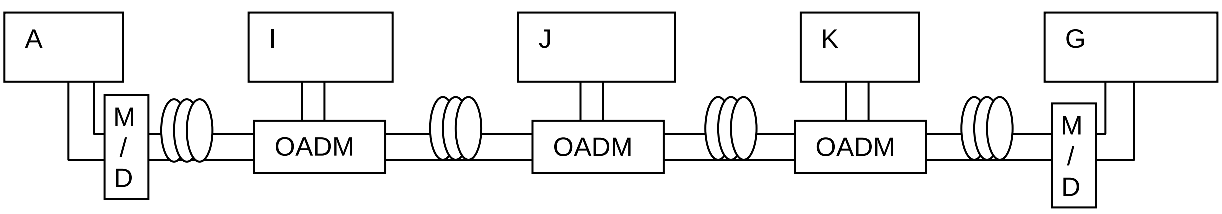


Figure B.7: Route 1 with DWDM 10 G transceivers and DWDM OADMs – optical amplifiers and compensators are required for express lambdas to work properly

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's 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's strongly related to actual 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.

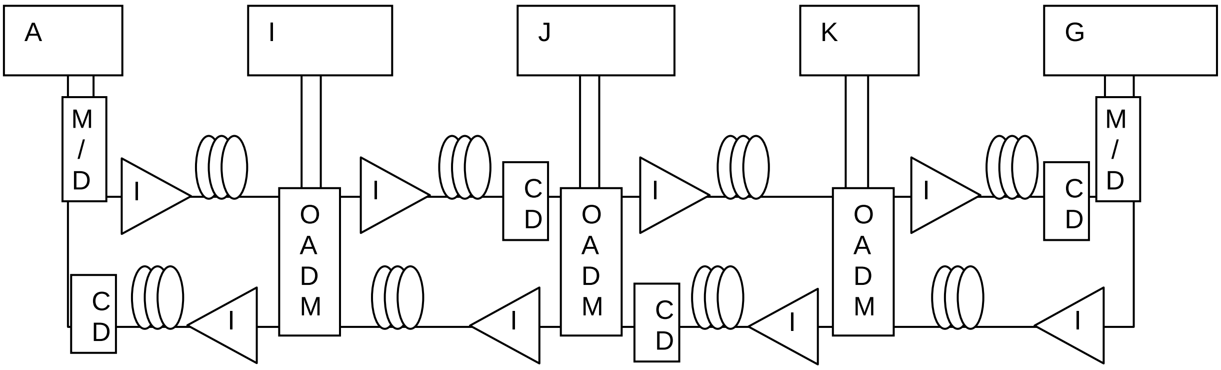
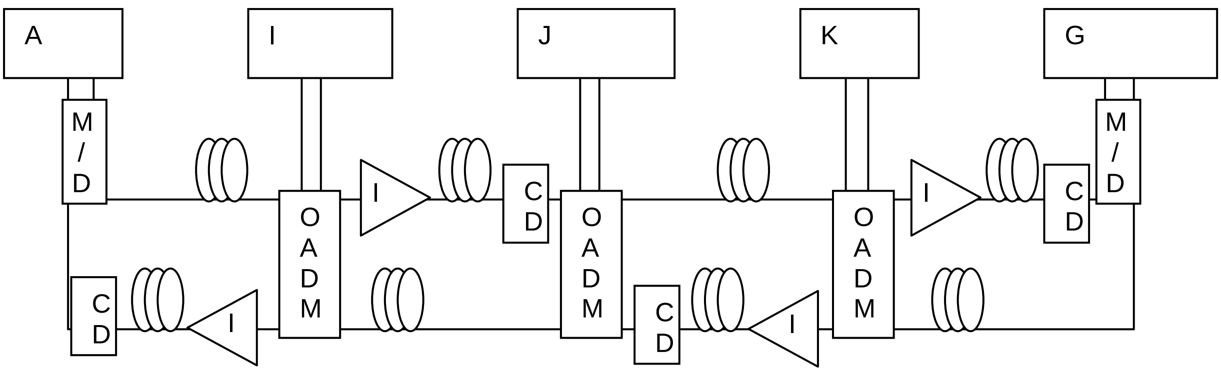


Figure B.8: Route 1 with DWDM 10 G transceivers and DWDM OADMs, amplifiers and compensators for Scenario 2b

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 goes for 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 mean that equipment will be cheaper. More realistic schema is depicted in Figure B.9.



Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

Figure B.9: More realistic schema for Route 1 with DWDM 10 G 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 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:

9 backbone PoPs

7 PoPs with 10 G capabilities

4 PoPs with 1 G 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:

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

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

Well, the situation here is more complex. The price of routing and switching equipment for Scenario 2a is the same as for Scenario 1 (it's 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 1 G capable switching equipment can be deployed in all non-backbone 11 PoPs. Only backbone PoPs are connected with express 10 G 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 1 G 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 have 3 backbone PoPs – A, I and G. But in Scenario 2a all PoPs along the route have to be capable to work with 10 G 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.

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

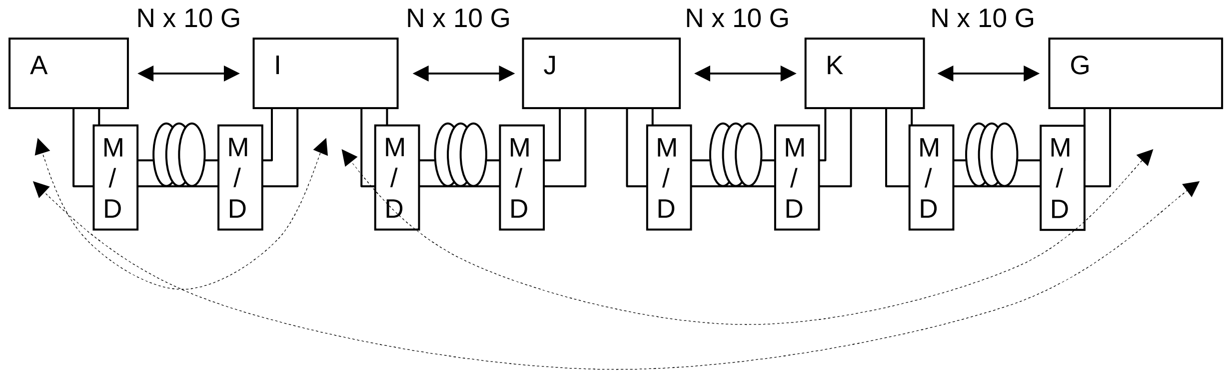


Figure B.10: Route 1 with 10 G equipment in all PoPs without possibilities to deploy express lambdas (dashed lines) – Scenario 2a

Scenario 2b which allows for express lambdas is depicted in Figure B.11. From this figure it's 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 10 G connections are considered A – I and I – G and two 1 G connections I – J and K – J. Similar approach has been used for all other routes and budgetary calculations.

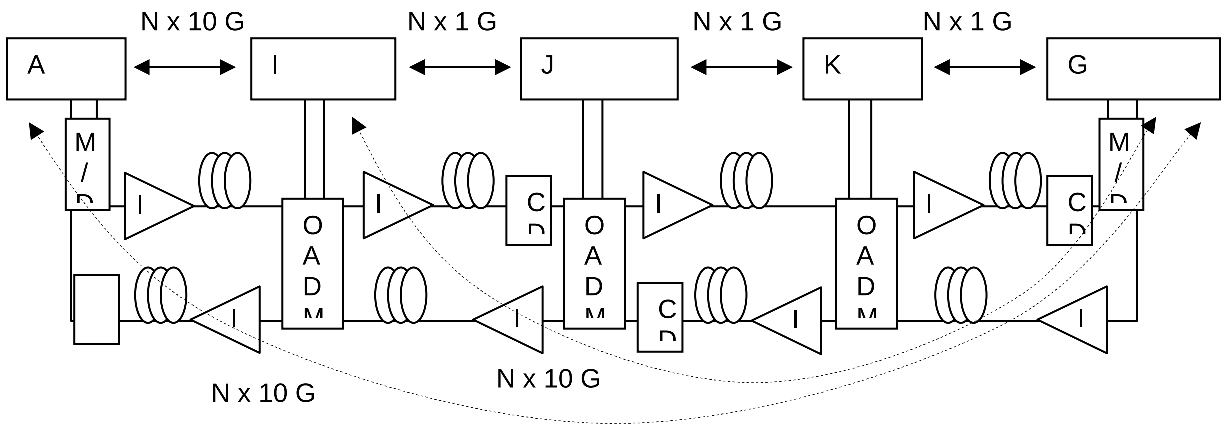


Figure B.11: Route 1 with 10 G equipment in 3 backbone nodes only – Scenario 2b

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

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.

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

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's 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 summarization and conclusions can be made. 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 quite comparable from an economical 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 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 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 more transmission components (Table 5.15) have to be deployed. It means that for a 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 then technical issues may be considered, and therefore it is more difficult to propose a feasible route. If it's 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's dependent on quality of fibres) so this distance may be the longest recommended fibre distance for a CBF route. NIL solutions canbe 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.

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 homogeneous 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 decide which area to choose as most of the organizations need to monitor various technologies from multiple vendors it must be clear that the 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 standard (RFC 1157) and platform neutral. For these reasons using SNMP by NOCs is a pre-requisite for any system monitoring.

There is a variety of paths for choosing 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 resolution help. These items should therefore drive the decision for network monitoring solutions to be deployed within NREN's NOC.

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

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 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 provides 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 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 to verify 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 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 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 suing 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 can 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 launch 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, draw and layout a map of networks, monitor services and alert you in case some service has problems. It supports SNMP, ICMP, DNS and TCP monitoring for devices that support it.
   - More information: http://www.mikrotik.com/thedude.php

When 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 application 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 available 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 free available and the most popular 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“

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001

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 digital circuit lease, a lease of a pair of optical fibres or one fibre.

End points of the circuit are under mentioned:

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 mention especially:

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) for case if the Association decides in future to rent the fibres between A-B points.
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 mention especially:

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 Term and course of performance

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

Within your tender mention suggested start date of provision of the service, at the latest .... In case of the lease of fibres it is necessary to deliver the service to users tests at least 3 working days in advance and herewith give in protocols about the measurement of attenuation and chromatic dispersion of the complete line and a document with the specification of the optical splitter and numbers of the terminals of the each end point of the line. The Organization is authorized not to accept the service, if the line does not fulfill 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 structure:

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 structure:

- 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 mention the earliest possible date of the conclusion of the agreement and the start date of projecting and realization.

6.2 Sanctions on supplier due to breach of contract shown in percentage of a monthly charge without discounts must be at least 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 term of the installation of the line the sanction on the supplier amounts 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 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 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.

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.

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

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

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 digital lambda circuit lease, a lease of a pair of optical fibres or one fibre.

End points of the circuit are under mentioned:

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 mention especially:

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 mention especially:

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

3 Term and course of performance

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

Within your tender mention suggested start date of provision of the service, at the latest .... In case of the lease of fibres it is necessary to deliver the service to users tests at least 3 working days in advance and herewith give in protocols about the measurement of attenuation and chromatic dispersion of the complete line and a document with the specification of the optical splitter and numbers of the terminals of the each end point of the line. The Organization is authorized not to accept the service, if the line does not fulfill 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 structure:

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 structure:

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 mention the earliest possible date of the conclusion of the agreement and the start date of projecting and realization.

6.2 Sanctions on supplier due to breach of contract shown in percentage of a monthly charge without discounts must be at least 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 term of the installation of the line the sanction on the supplier amounts 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 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 agreement must be signed by statutory authority, or by another warranted representative; in this case the original or officially authentic copy of this authorisation must be attached to 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, that 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 an economic convenience and according to the criteria mentioned below with down going 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, that the offer for fibre rental includes expensive construction of the first mile. Organization will multiply the offered prices for digital circuit rentals 6 (six) times for the purpose to compare with offered rental prices, the.

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 closed envelope designated with the name „………..“, the stamp and the address of the supplier. The supplier must specify explicity 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 with up-going continual line. The supplier will deliver the offer also in electronic form on CD, the draft of the contract in electronic form will be delivered in MS Office format or compatible.

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

Project: Porta Optica Study
Deliverable Number: D3.2
Date of Issue: 03/07/07
EC Contract No.: 026617
Document Code: POS-15-001