Document 17
Asset Category – BT21
EPN

Asset Stewardship Report 2014

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Document History

Version	Date	Details	Originator	Revision Class	Section Update
1		Baselined July 2013 submission	David Jeyakumar		
1.1	11/02/2014	Updated RIGs mapping	David Jeyakumar	Major	1.1
		Aligned cost and volume data and graphs to RIGs			1.3, 7.4, Appendix 5
		Updated NPV graph			5.2
		Amended commentary to show comparisons between FBPQ submission, DPCR5 forecasts, and ED1 forecasts, following consultation with Steve Mockford.			7.5
		Updated full programme. Removed information on specific solutions as this is commercially sensitive.			Appendix 9
1.2	14/02/2014	Clarified that there are no 33kV BT Private wires on record in EPN, following feedback from Kevin Burt.	David Jeyakumar	Minor	2.2
		Added definitions of Capital and Operational expenditure in Glossary, following feedback from Kevin Burt			1.6
1.3	14/02/2014	Added Appendix 10: mapping table showing RIGs mapping for ED1 expenditure and volume, using template tables.	David Jeyakumar	Major	Appendix 10
1.4	20/02/2014	Submitted to Steve Mockford for approval	David Jeyakumar	Minor	
1.5	25/02/2014	Minor amendments and corrections following review by Barry Hatton	David Jeyakumar	Minor	5.2.1 6.0 7.6.1 7.6.2 7.7.2
1.6	26/03/2014	Updated RIGs mapping to align with S&R updates	David Jeyakumar	Major	1.1, 3.1 Appx10
2.0	27/03/2014	Final for publication	Regulations	Minor	All

Contents

1.0 Executive Summary

1.1 Scope

This document details the drivers of UK Power Networks' BT21CN Mitigation programme, the intervention policies applied and its expenditure requirements.

There are 138 rented BT private wires in use for 132kV Teleprotection. With BT's migration to an IP-based communication protocol by 2018, the electricity network will be at risk due to the non-deterministic nature of IP networks. Malfunction of protection systems, due to Teleprotection failure, may result in extended outages to an otherwise healthy network, increased damage at the point of fault, overstressing of other plant and equipment, risk to personnel and members of the public, and potential non-compliance with ESQC regulation.

The BT21CN programme installs a fibre communication platform to provide the Teleprotection paths currently serviced by BT private wires. A mixture of self-build and leased fibre has been identified as the most effective strategy on the 132kV network, delivering a technically compliant solution with the lowest whole life cost. There are no known BT private wires in use for 33kV Teleprotection in EPN.

Fibre installation costs are held in the following locations in Ofgem's and UK Power Networks' investment planning documents:

Investment type	NAMP line	RIGs Expenditure	RIGs Volumes
Installation of optical fibre schemes in DPCR5	1.26.10	CV9a row 13	CV9a row 110 (km of pilot wire) V4a rows 103 104 (additions and disposals of overhead and underground pilot wire)
Installation of optical fibre schemes in ED1 2016-2018	1.26.10	CV10 row 6	CV10 row 6 (number of schemes) V4a rows 103 104 (additions and disposals of overhead and underground pilot wire)
Installation of optical fibre schemes in ED1 2019-2023	1.26.10	CV105 row 7	No volume entries in CV105 row7 V4a rows 103 104 (additions and disposals of overhead and underground pilot wire)
Operations, maintenance and monitoring of fibre network	2.28.31. 6780	CV10 row 7	CV10 row 7 (number of schemes)

Table 1 – Mapping of BT21CN Mitigation costs

1.2 Investment Strategy

Investment in a communication platform that will replace existing BT private wires by the end of 2017 will fully mitigate the risk to the network before BT's withdrawal of service in 2018.

Continued installation of fibre in alignment with asset replacement projects is planned beyond 2018 to increase resilience in the fibre network and gradually reduce reliance on third-party leased fibre.

1.3 ED1 Proposals

Investment forecast (£m)

BT21 Investment (£'m)	ED1								
Year end	2016	2017	2018	2019	2020	2021	2022	2023	Total
Capital	6.90	4.82	2.69	0.01	0.12	0.01	0.13	0.25	14.94
Operational	0.87	1.09	1.32	1.38	1.38	1.38	1.38	1.38	10.18

Table 2 – Investment in the ED1 period

1.4 Innovation

An EPN-wide fibre optic communication system could assist in enabling a smart grid-ready network and more distributed generation, thus helping the UK deliver on its commitment to reducing carbon emissions.

1.5 Risks and Opportunities

	Description of similarly likely opportunities or risks arising in ED1 period	**Level of uncertainties/cost growth (£m)**
Risk	Unexpected overhead line condition	0.743
Risk	Reduction in opportunities to install fibre in alignment with other asset replacement projects	0.143

Table 3 – Risks and opportunities

1.6 Glossary

Alignment	Installation of fibre as part of a non-BT21 condition-based or load-driven asset replacement project (referred to as an asset replacement project), where the corresponding BT21 scheme provides only the incremental cost of fibre
AS&P	Asset Strategy and Performance: a department of Asset Management at UK Power Networks that manages the condition-based asset replacement programmes
Asset replacement project	A non-BT21 condition-based or load-based project to replace conductors or underground cables (see Alignment)
Blocking protection schemes	Transfer of a signal from one site to another remote site to prevent or change the characteristics of an operation
BT	British Telecom
BT21CN	British Telecom 21st Century Networks
BT21CN Mitigation programme	UK Power Networks programme to mitigate the risk of BT21CN by deploying optical fibre and radio frequency communication
BT21CN scheme or BT21 scheme	A component within the BT21CN Mitigation programme to install optical fibre or radio frequency communication paths between two specified sites
Capital expenditure	Referred to as either capital expenditure or installation cost, this is the cost of end-to-end installation, testing, and commissioning of an optical fibre scheme
Cormon	An overhead line corrosion detector used to test steel-cored aluminium conductors at 33kV and above for signs of corrosion

Fibre wrap	Fibre cable that is wrapped around an existing earth or phase conductor
Installation cost	See Capital Expenditure.
Intertripping protection schemes	Protection scheme where the trip signal is transferred from one location to another remote location to effect the operation of a piece of plant or other action
Leased dark fibre	A dedicated fibre route rented from a third-party provider who owns the route
OHL	Overhead line
Operational costs	The cost of testing, monitoring, and maintaining an optical fibre scheme following complete installation.
OPGW	Optical Ground Wire (earth conductor with embedded fibre)
OPPC	Optical Phase Conductor (phase conductor with embedded fibre)
Self-build optical fibre	Any fibre solution that is built and owned by UK Power Networks, including OPGW, OPPC, fibre wrap and underground fibre
Unit protection schemes	Protection scheme where the protection zone is defined by location of current transformers forming part of the overall scheme

2.0 Description of British Telecom Private Wire Population

2.1 BT Private Wires

A number of protection schemes isolate and protect large items of electrical plant under fault conditions, including intertripping, blocking, and unit protection on the 132kV and 33kV distribution systems.

The protection schemes rely upon Teleprotection signalling, which is delivered over a variety of telecommunications circuits with clearly defined characteristics.

Within EPN, circuits leased from BT, known as BT private wires, provide the communication paths for all 132kV intertripping schemes. As a consequence, EPN is currently dependent on the continued availability of leased services for the safe, secure and compliant operation of the distribution network.

2.2 Population

In EPN, 138 BT circuits are currently leased by UK Power Networks for protection signalling on the 132kV distribution network. There are no known BT private wires in use for 33kV Teleprotection in EPN.

2.3 Withdrawal of Current Service

The Electricity Networks Association (ENA) was advised by BT in 2004 that current Teleprotection services would be withdrawn in 2018 following an upgrade of BT's telecoms network to an IP-based system known as BT21CN.

3.0 Investment Drivers

3.1 Mitigation of Network Risk

3.1.1 Network risk

Due to the non-deterministic performance of IP networks, it was established that the current UK Power Networks' 132kV protection schemes are unlikely to function in accordance with requirements when migrated to the BT21CN alternatives. Additionally, the protection schemes will not be compliant with ENA TS 48.6.7 (Communications for Teleprotection Systems), which states the parameters of telecommunications circuits to be used for Teleprotection.

The results of non-compliance could be severe. Malfunction of protection systems due to failure of BT communication links may result in extended outages to an otherwise healthy network, increased damage at the point of fault, overstressing of other plant and equipment, risk to personnel and members of the public, and potential non-compliance with ESQC regulation.

3.1.2 Mitigation

Due to the severity of the potential failure, a communication platform must be created to replace every BT communication link currently in place in EPN.

There are no existing owned or leased telecoms network platforms capable of supporting an appropriate solution to fully mitigate the risk of BT21CN. The only way to ensure a timely mitigation of the identified risk is to programme communication infrastructure deployment during both the DPCR5 and ED1 periods.

As a result, a UK Power Networks' BT21 team was established in 2008 to evaluate all viable options for mitigation of BT21CN, along with the associated risks and costs.

The recommendation of the team was a combination of a self-build optical fibre telecoms network and leased dark fibre with alignment. This was calculated to be the most cost-effective way to deliver a fibre network to mitigate BT21CN (refer to section 5.2). It provides 57% of the proposed overall network infrastructure as self-build by 2020 if all alignment works go ahead. If some alignment projects are postponed, e.g. after asset condition testing, there is still flexibility to rearrange BT21 project dates or to deploy dark fibre instead. However, continued alignment is also highly recommended beyond 2020 as this serves to gradually reduce reliance on third parties.

Ref NAMP Lines

Capital investment/installation
1.26.10.0020/5236/5237/5240/5241/5242/5244/5245/5247/5251/5253/5256/5257/5263/5266/5267/5268/5269/5274/5276/5277/5279/5280/5281/5288/5290/

5292/5294/5300/5307/5313/5314/5319/5321/5323/5324/5325/5326/5327/5328/5329/5331/5332/5333/5334/5335/5336/5337/5338/5339/5340/5341/5342/5343/5344/5345/5346/5347/5348

Operational requirements

2.28.31.6780

Ref RIGs code

CV9a, CV10, CV105, V4a

4.0 Asset Assessment

4.1 Asset Health

Not applicable. Health indices data does not apply to BT private wires.

4.2 Asset Criticality of Existing BT Private Wires

BT private wires currently provide the communication paths for a significant proportion of 132kV protection signalling schemes. EPN is dependent on their continued and reliable functioning for the safe, secure and compliant operation of its distribution network.

4.3 Network Risk

The risk posed to the network is the migration from the current service to a non-deterministic IP-based service. Teleprotection schemes functioning on BT21CN networks have been established to be non-compliant and unlikely to function in accordance with requirements.

This risk is the investment driver for the BT21CN Mitigation project. Refer to section 3.1.

4.4 Data Validation

Not applicable.

4.5 Data Verification

Not applicable.

4.6 Data Completeness

Due to the severity of a Teleprotection circuit failure, every communication path currently provided by BT private wires must be migrated to the proposed fibre communication platform.

An audit of BT private wires in EPN was carried out, and the list of circuits to be mitigated was updated in September 2012.

The audit was carried out by UK Power Networks' Teleprotection engineers and ensures the communication paths affected by BT21CN have been identified, enabling deployment of a solution that fully mitigates the risk.

5.0 Intervention Policies

5.1 Interventions: Description of 132kV Intervention Options

UK Power Networks' BT21 team explored the viability of a variety of technologies for the mitigation of BT21CN on 132kV Teleprotection schemes. Of these, the following were rejected:

- Copper cables
- Radio systems
- Circuit breakers
- Power Line Carriers.

The following were identified as suitable technical solutions:

- Self-build fibre
- Leased third-party dark fibre.

The suitable options are summarised in Table 4.

Comaprison of the viable optical fibre solutions for BT21CN Mitigation on the 132kV Network

	Description	Resilience	CAPEX	OPEX	Estimated Asset Life
Self build - OPGW	Earth Wire with 48 fibre embedded core	Fully resilient end to end solution	High unless installed in alignment with reconductoring	Low	40 years
Self build - OPPC	Phase Conductor with 48 fibre embedded core	Fully resilient end to end solution	High unless installed in alignment with reconductoring	Low	40 years
Self build - Fibre wrap	A 48-fibre optical fibre cable wrapped on conductor	Not a fully resilient solution	Low	Low (but higher than OPGW and OPPC)	15 years
Self build - Under-ground Fibre	2 underground ducts of 24 fibres each	Fully resilient end to end solution	Very high unless installed in alignment with cabling	Low	40 years
Leased Dark Fibre	One pair of fibres leased from a third party network owner	Not a fully resilient solution, unless two completely diverse dark fibre routes	Dependent on extent of new dig required to connect into grid site	High	10, 7, or 5 year renewable rental contract.

Table 4 – Comparison of the viable fibre optic solutions for BT21 on the 132kV network

The following sub-sections provide more information on all the options considered.

5.1.1 Self-build fibre installation

This is the creation of fibre routes using existing overhead line infrastructure or, where this is not available, underground fibre routes. This solution is wholly owned by UK Power Networks.

- OPGW (optical ground wire)

  Earth wire with a 48-fibre embedded optical core.

  Direct replacement to conventional earth wires.

  Tried and tested method of installing fibre.

  This is the most reliable solution, as the fibre cores are well protected at the central core of the conductor and wire breakage is very rare.

  Can be used in a “flattened ring” architecture, where a single conductor provides a fully resilient fibre link.

  High installation cost, but cost effective when installed in alignment with earth wire reconductoring projects.

  As long as the conductor is intact, the fibres will continue to function. Asset life is taken to be the estimated lifetime of the overhead conductor: 40 years.

- OPPC (optical phase conductor)

  Phase conductor with a 48-fibre embedded optical core.

  Direct replacement to conventional phase conductors.

  May require replacement of all three phase conductors due to the differing sag of old and new conductors.

  High installation cost, but cost effective when installed in alignment with phase conductor reconductoring projects.

  As long as the conductor is intact, the fibres will continue to function. Asset life is taken to be the estimated lifetime of the overhead conductor: 40 years.

- Fibre wrap (on both earth and phase conductors)

  A 48-fibre optical cable helically applied on existing earth or phase conductors, using a purpose-built wrapping machine.

  Lower installation cost than OPGW or OPPC.

  Faster installation than OPGW or OPPC, thus requiring shorter outages.

  Fibre wrap is exposed to the environment and particularly vulnerable to shotgun damage, especially with reduced clearance of 132kV.

  Therefore, a single fibre wrap route is not a point-to-point resilient solution.

  The fibre wrapping machine is heavy. Due to health and safety reasons, the BT21 policy states that only conductors with Cormon condition one or two can be fibre wrapped; condition three and four conductors are considered too corroded to safely support the weight of the machine.

  Based on a history of failures in other DNOs, members of the Electricity Networks Association Next Generation Networks (ENA NGN) group agreed that 15 years is the expected asset life of fibre wrap.

- Underground fibre

  Expensive as an end-to-end solution.

  Cost effective when installed with other excavations, such as cable reinforcement schemes, or where spare ducts are available.

  Underground installation is used to connect fibre from the overhead network into substation relay rooms, or to connect from relay rooms to a dark fibre hand-off point.

  Usually installed as two ducts containing 24 fibres each, with vertical separation between ducts; therefore this is a fully resilient solution because of the separation and protection afforded by underground installation.

  Due to the protection provided by underground installation, especially when installed with HV cables, the asset life is estimated to be equal to that of cable installations: 40 years.

Figure 1 – Fibre wrap installed on an overhead line

Figure 2 – The fibre wrapping machine at work

Figure 3 – OPGW

Images credits: AFL Global

5.1.2 Leased third-party dark fibre

This is technically viable for BT21CN as the use and installation of terminal equipment for the optical fibre circuit will be under the control of UK Power Networks across a dedicated fibre circuit.

However, the dedicated route consists of only one pair of optical fibres. This suffices for Teleprotection requirements, so long as multiplexers are employed.

A single dark fibre pair is not considered a fully resilient solution due to the reliance on third-party service. However, two fully diverse dark fibre routes between two points provide a fully resilient fibre solution between those two points.

Subject to agreement by the supplier, dark fibre could potentially be presented at any location, such as a substation wall or 132kV tower, as long as the demarcations are clearly identified. The leased fibre cables can then be spliced to the self-owned fibre cable and provide short- or medium-term solutions until such a time as a complete self-build solution can be installed.

Cost of installation depends heavily on distance of new digs required to connect dark fibre into UK Power Networks' grid sites.

Dark fibre routes have significant rental costs compared to self-build fibre maintenance costs, and rental costs are dependent on route length.

A dark fibre lease contract can be five, seven, or 10 years. Whole life cost calculations for schemes delivered so far demonstrate that a 10-year contract provides the most cost-effective solution. Therefore five- and seven-year dark fibre rental schemes have never been implemented.

5.1.3 Copper telecoms cables (rejected option)

UK Power Networks owns and operates a small number of pilot and twisted pair copper telecoms cables in certain areas of EPN. These were traditionally laid with HV cables and are found more in urban than rural areas. However, in most cases, these cables are already in use for Teleprotection services. Therefore, these cables cannot form a major component of the overall BT21CN Mitigation strategy.

Lease of third-party managed services over copper have been considered by UK Power Networks. However, only BT and Cable & Wireless have offered a managed copper solution and neither could provide assurance of the required level of contractual compliance.

5.1.4 Radio systems (rejected option)

Although microwave and other radio spectrum options offer potential solutions for standby protection bearer services, due to concerns expressed by protection engineers regarding this technology being used for primary protection, it was recommended that a microwave/radio-only option is rejected.

Furthermore, the electricity industry protection and telecoms managers are in agreement that 132kV and above protection schemes should not use a radio bearer service as its primary Teleprotection solution.

However, where ENA TS 48.6.7 Category 3 circuits are considered suitable Teleprotection schemes, radio frequency communication can provide a very-cost effective solution. Therefore, such schemes used for 33kV intertripping could benefit from this solution.

5.1.5 Circuit breakers (rejected option)

In the case of 'simple' transformer feeders, which are radial to the main network, installation of transformer HV circuit breakers has been considered an alternative to establishing communications to the substation. This option was initially proposed where installation of 132kV circuit breakers is feasible at the substation site and provides the most economical solution to maintain existing network security and reliability. However, dark fibre options are more cost effective and therefore circuit breakers are no longer recommended by the BT21 team.

5.1.6 Power line carrier (rejected option)

Legacy PLC systems are in service on the UK transmission network, but the power levels are restricted, as are the number of available channels.

There are a limited number of 132kV feeders where PLCs could be installed. However, due to network configuration and space constraints within the grid substation sites for the very expensive terminal equipment, this option is only suitable at specific sites and it was recommended that this option is rejected.

Currently there are no PLC systems in use on the UK Power Networks' network, and the introduction of this technology will create additional issues in asset management, network operation and staff familiarisation and training.

5.2 Policies: Selecting Preferred 132kV Interventions

Following BT's announcement of the withdrawal of current communication services, the Electricity Networks Associations Next Generation Networks (NGN) Group has held regular meetings to discuss the mitigation options.

The consensus from these meetings was that a wholly OPGW and underground fibre network would provide the most reliable and longest lasting solution for mitigation of BT21CN. This stemmed from the experience of OPGW and underground fibre across the UK and Europe. Embedded fibres will last as long as the conductors are in place to protect them, and underground fibre, though at higher risk of damage, is easily and cheaply repaired.

Following the initial evaluation of technologies by UK Power Networks' BT21 team (refer to section 5.1); a self-build fibre deployment strategy was considered, along with a number of other options, as detailed in Table 5.

Option number	Description
1	Self-build without alignment
2	Self-build with alignment
3	Leased dark fibre with alignment
4	Leased dark fibre without alignment
5	Self-build and leased dark fibre with alignment

Table 5 – Fibre deployment strategies

Cumulative NPV analyses of these options, summed across both EPN and SPN distribution networks, are shown in the graph below.

The cumulative cost is calculated over the 'implementation' period (2010-2018) and the 'in service' period (2018-2058) of 40 years. This period was chosen as this is the expected lifetime of OPGW and OPPC – the longest lasting of the options.

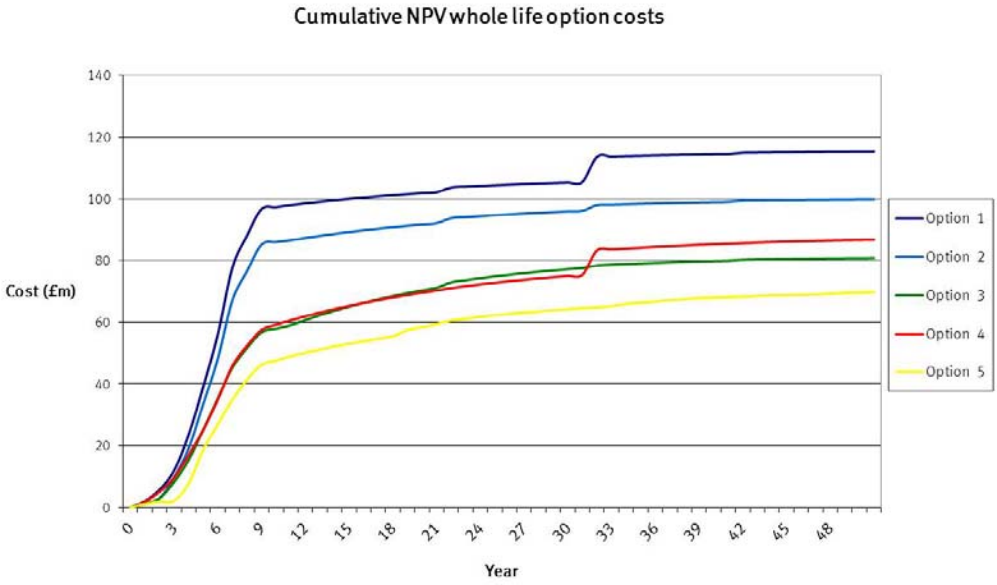


Figure 4 – Cumulative NPV whole life costs (options 1-5)

Option five is the strategy with the lowest whole life cost, on account it considers ***all*** technically viable options for each optical fibre scheme and determines the lowest whole life cost solution for that scheme. Therefore, Option five was the chosen strategy for BT21CN Mitigation in DPCR5 and it is the recommended strategy for continuation of the programme in ED1.

Although a wholly self-built fibre network (options one and two) provides the most technically reliable and robust solution, the additional reliability is marginal in relation to the additional cost compared to option five.

A wholly dark fibre solution (option three) and a dark fibre plus alignment solution (option four) were rejected due to their cost and the high reliance on third-party services.

In implementing option five, each BT21 scheme, i.e. each end-to-end fibre route, needs to be evaluated under the following considerations, in order:

1. Alignment and OHL condition
2. Resilience
3. Whole life cost calculation
4. Feasibility studies.

This decision-making process is explained in the following sub-sections and the intervention flowcharts at the end of this section.

5.2.1 Alignment and OHL condition

Alignment is the installation of optical fibre in conjunction with an existing conductor or cable replacement project, known as an asset replacement project.

For example, where the earth wire is being replaced due to its condition, OPGW will be installed instead of the standard HORSE conductor. Another example is where 132kV underground cables are being replaced as part of a reinforcement programme, telecoms ducts and optical fibres will be installed (in the configuration described in section 5.1).

Alignment is the most cost-effective method of fibre roll-out because the BT21 scheme pays for only the incremental cost of fibre and therefore it is the first possibility to be considered.

The incremental costs of fibre for alignment projects are given in the table below;

Type of installation	**Incremental cost for alignment works (£/metre)**
OPGW (over standard HORSE)	4.797
OPPC (over LYNX, SYCAMORE, UPAS)	5.954
UG (install duct only) coincident with main cable laying works.	5.180
UG (install duct and fibre) coincident with main cable laying works.	13.320

Table 6 – Incremental cost of fibre in alignment schemes

The first consideration is whether there is an existing asset replacement project scheduled before 2018, which the corresponding BT21 scheme can align with. If so, fibre installation via alignment can go ahead.

If not, the next consideration is whether there is an asset replacement project scheduled for post-2018 with which alignment can happen. If there is, the possibility of bringing forward this project prior to 2018 must be evaluated. However, this may be unviable because:

- An NPV analysis demonstrates there is not an overall cost benefit (i.e. considering both BT21 and the asset replacement programme).
- It is unsure if the project will go ahead. For example, a cable reinforcement project may be dependent on a potential future

event, such as the connection of a large housing development or generation scheme, which may only be confirmed after 2018.

If there is no project to align with, or if bringing forward a project is shown to be unviable, the next consideration is OHL condition. Existing Cormon (corrosion monitoring) data is consulted to determine whether the conductors can be fibre wrapped.

If no recent (less than six years old) Cormon data is available, Cormon tests must be carried out. The results will have implications on whether a line can be fibre wrapped or not. The decision on this, along with the corresponding asset replacement strategy, is show in Table 7.

Cormon condition	Fibre wrap possibility	Condition-based asset replacement strategy
1	Can be fibre wrapped	Healthy conductor
2	Can be fibre wrapped	Healthy conductor
3	Partially corroded. Cannot be fibre wrapped	Increased frequency of Cormon testing to every five years to monitor the line
4	Severely corroded. Cannot be fibre wrapped	The line shall be considered for restringing (EDS 01-003 Refurbishment and Replacement Standard for Broad Based Towers)

Table 7 – Cormon condition

If the conductor is found to be condition four, this will be brought to the attention of UK Power Networks' Asset Strategy and Performance team, which manages the condition-based replacement programme. The strategy will be to schedule the route for reconductoring and, as it is critical for BT21CN Mitigation, will be scheduled for pre-2018 so that the corresponding BT21 scheme can install OPGW optical fibre in alignment.

If the line is measured to be condition one, two or three, there is no justification for considering alignment in the BT21 scheme, so the next step is to assess the resilience requirements of the scheme (refer to section 5.2.2).

5.2.2 Resilience

All 132kV Teleprotection circuits require (N-1) resilience, and the configuration of a BT21 scheme will determine how this is provided. A fibre link is configured as either a segment of a main self-healing fibre ring where alternate routing is available in the event of a fibre break, or as part of a spur extending off a main ring.

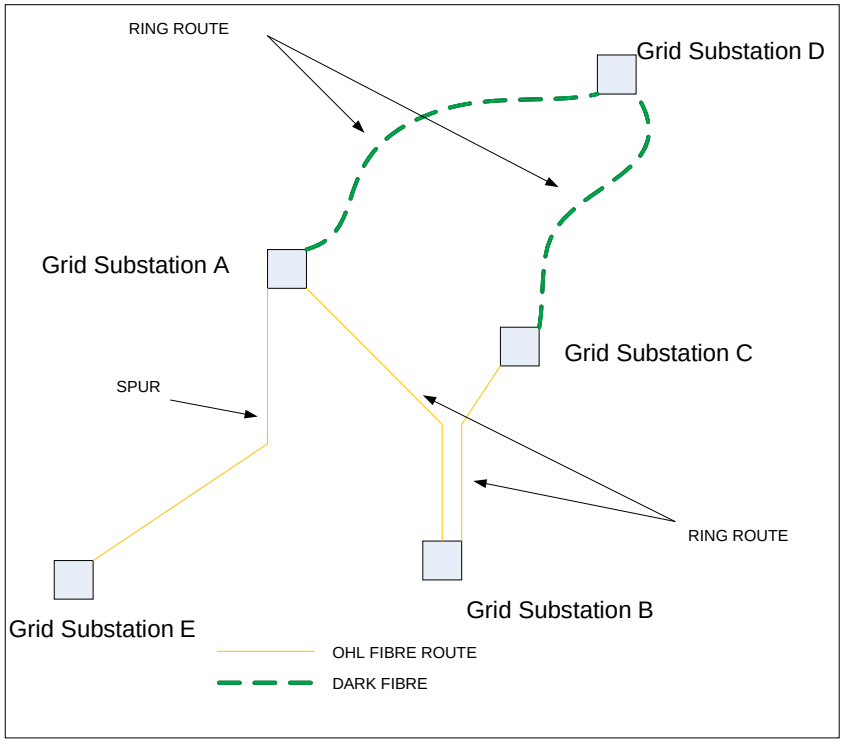


Figure 5 – Ring architecture with a single spur

For a ring route, the resilience requirements are fulfilled by:

- Fibre wrap (provided Cormon condition one or two)
- Single leased dark fibre pair
- OPGW
- OPPC
- UG fibre

For a spur route, the resilience requirements are fulfilled by:

- OPGW
- OPPC
- Two fully diverse leased dark fibre pairs
- One leased dark fibre pair plus fibre wrap (provided Cormon condition one or two)
- Two fibre wraps (provided Cormon condition one or two) (can be on earth and phase conductor; or both on phase conductor with one on each circuit, assuming dual circuit overhead line)
- UG fibre

As explained in section 5.1.1, a single OPGW, OPPC or underground fibre link is considered to be a fully resilient solution with flattened-ring architecture.

It is often difficult to obtain two fully diverse dark fibre routs as there are often pinch points in the network (e.g. across bridges) that present a single point of failure.

Fibre wrap in combination with a single dark fibre pair has not been applied in previous solutions as the whole life cost analysis favours OPGW.

It must also be noted that an end-to-end self-build underground fibre solution is very rare, and is never viable between sites that are connected predominantly by overhead line, and so is not considered for such schemes.

It does become an option between sites connected by underground cable, or where the overhead route is long because it follows an indirect path, but these instances are rare.

Underground installation becomes more viable if spare ducts are available on an existing cable route between the sites.

5.2.3 Whole life cost calculation

Once resilience has been accounted for and the options for fibre installation shortlisted, the next step is the comparison of the options via a whole life cost model.

A whole life cost evaluation is required to account for the significant operational cost requirements of fibre links, hence ensuring that the most cost-efficient long-term solution is identified.

The whole life cost model is further broken down to provide estimates of the component costs that make up the installation cost of a BT21 scheme. These models are based on the pricing of the 2012 programme and consultation with contractors and equipment suppliers on resourcing and installation rates.

The inputs to these models are scheme data collected via desktop route studies (route length, underground lengths, crossings, etc.). High-level quotes from the dark fibre service provider are used in this model to calculate the installation costs and rental of a dark fibre option.

The capital investment and operational costs for each option are then fed into a Net Present Value (NPV) analysis, which produces the whole life cost of each option over 40 years (the expected lifetime of OPGW and OPPC). The expected lifetime of fibre wrap is 15 years; therefore the whole life cost analysis factors in the expenditure for re-wrapping in years 15 and 30. It is also assumes that dark fibre rental increases by 10% at every renewal of contract (whether a five-, seven-, or 10-year contract).

The option with the lowest whole life cost is put forward for feasibility study and detailed costing.

5.2.4 Feasibility studies

Each year, a programme of BT21 schemes, each with their proposed solution obtained from whole life cost analysis, is taken forward for feasibility studies and detailed costing by an appointed contractor. The results of the studies may affect the proposed options in terms of highlighting more cost-efficient solutions.

***For a visual representation of the intervention evaluation process and whole life cost models, please see the flowcharts* below.**

For case studies of how the intervention process has been applied for actual schemes, see Appendix 4 WLC Case Studies.

BT21 SCHEME INTERVENTION FLOWCHART

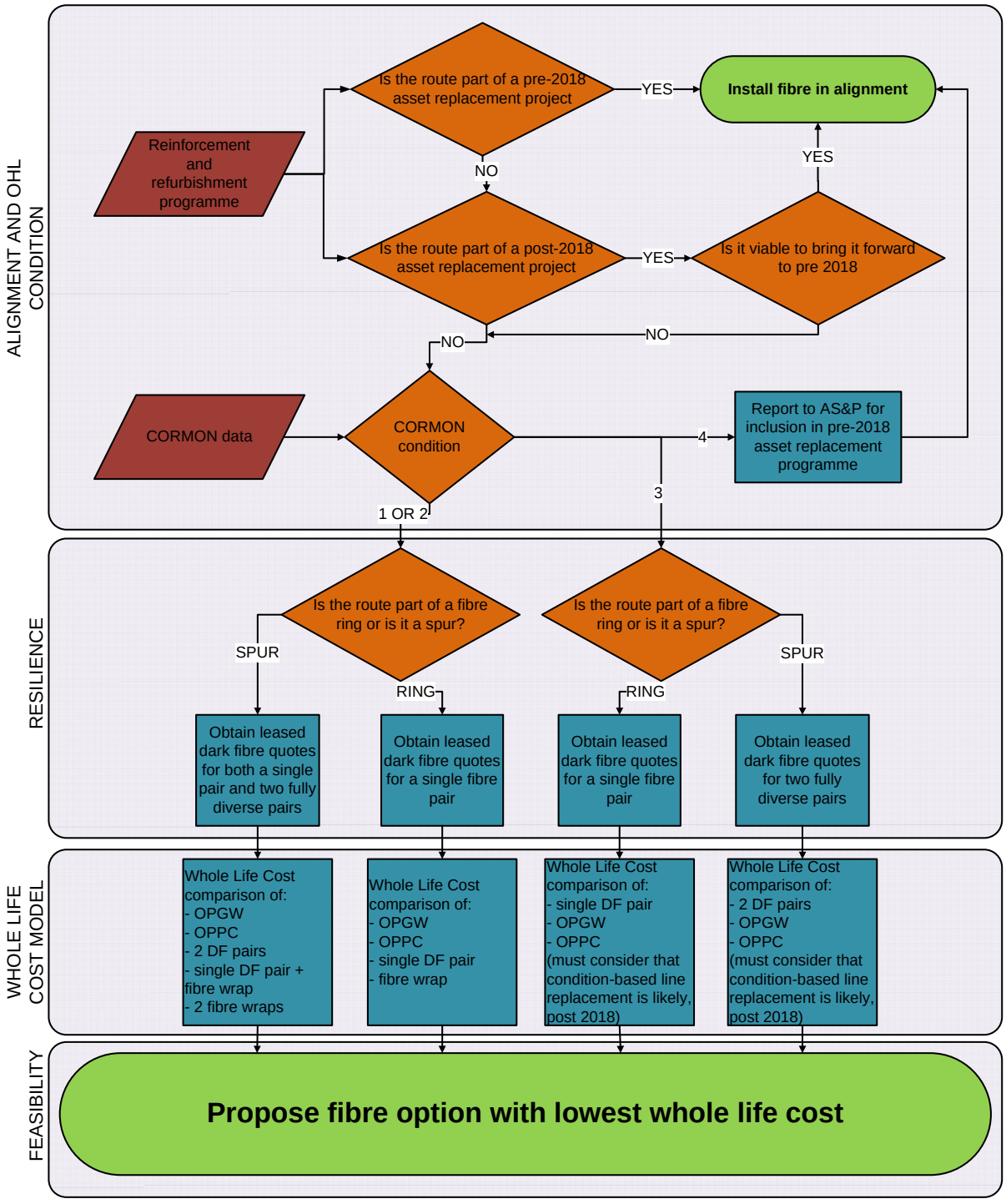


Figure 6 – BT21 scheme intervention flowchart

Self Build Fibre Whole Life Cost calculation

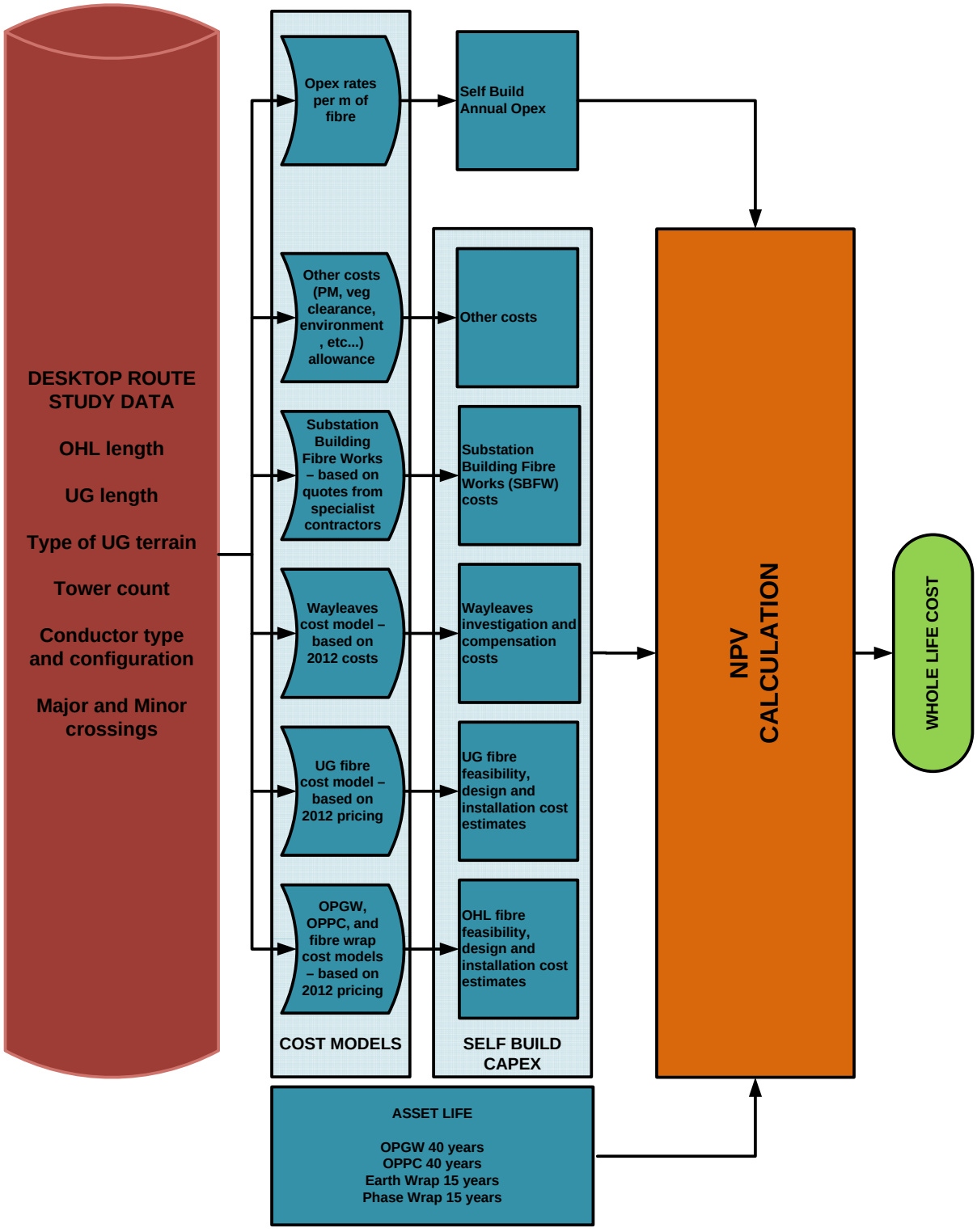


Figure 7 – Self-build fibre whole life cost calculation

Leased Dark Fibre Whole Life Cost calculation

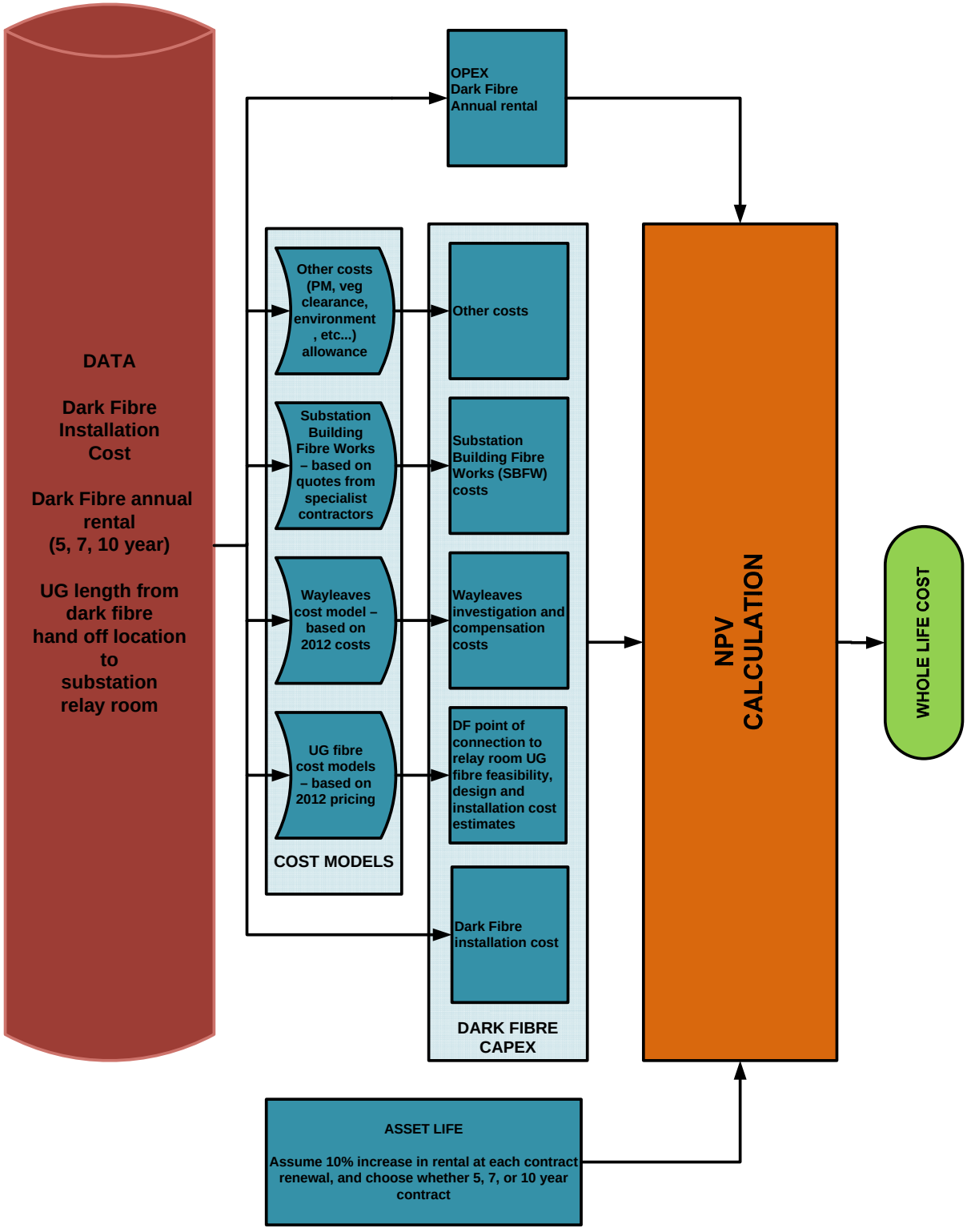


Figure 8 – Leased dark fibre whole life cost calculation

6.0 Innovation

While outside the scope of the BT21CN Mitigation programme, the fibre communication platform produced by the programme will be an enabler of active network management and improved network capacity to connected distributed generation via duplicate intertripping instead of Directional Over Current protection.

An EPN-wide fibre optic communication system will therefore assist in enabling a smart grid-ready network, helping the UK deliver on its commitment to reducing carbon emissions.

7.0 ED1 Expenditure Requirements for BT21CN Mitigation

7.1 Method

In anticipation of BT's withdrawal of service in March 2018, an optical fibre network must be in place by the end of 2017 to provide 100% of the communication paths currently provided by BT private wires.

7.2 Constructing the Plan

Deployment of the first optical fibre routes under the BT21CN Mitigation programme commenced in 2010.

The pricing schedules provided by contractors for the programme led to the creation of new models for cost forecasting.

These models have been applied to forecast the expenditure of the BT21CN programme for 2013 onwards.

The programme is constructed to ensure full mitigation of BT21CN by the end 2017.

For each 132kV BT21 scheme, a high-level options evaluation has been carried out, as described in section 5.2, with the exception of the feasibility study, as this needs to be carried out by the contractor at the beginning of each annual programme. This process only highlights the most likely fibre solution for the scheme.

Where dark fibre quotes are not available, the route length is compared with that of other routes for which quotes are available to produce an estimate of installation and rental costs.

Where recent (less than six years old) Cormon data is not available for a scheme, existing data is used. Therefore, if the scheme is evaluated to be a

fibre wrap solution, there exists a risk that this option might not be feasible if the Cormon condition has deteriorated significantly since the last test. The schemes at risk have been identified and the impact of the risk has been calculated in Appendix 8 Risk Assessments: Overhead Line Condition.

As part of the intervention policy, all opportunities are explored to align with condition- or load-based 132kV conductor or cable replacement projects. The current 132kV refurbishment and reinforcement programmes have been consulted in constructing the plan.

The risk of reduction in alignment due to cancellation or deferral of alignment projects, and the impact of such events, is presented in Appendix 8 Risk Assessments: Reduced Alignment.

Alignment with asset replacement projects will continue beyond 2018 to increase resilience on the network and reduce reliance on third-party leased fibre. Although not all post-2018 schemes have been identified, allowances are required to ensure that any future opportunities to install fibre are utilised.

When other major works are planned to occur before 2018 where the conductor is not being replaced, e.g. insulator and fittings replacement, the corresponding self-build BT21CN scheme is planned to occur alongside it to achieve potential efficiencies in outages, mobilisation and resource.

Effort is made to ensure routes in geographical proximity and involving the same substations are completed simultaneously to achieve efficiencies in cabling works and resource.

7.3 Additional Considerations

Strategic infrastructure proposals in the pipeline could affect the 132kV network structure. Close liaison with UK Power Networks' Infrastructure Planning is on-going to keep abreast of these proposals and ensure that any effect on BT21CN schemes is identified and assessed.

7.4 BT21CN Mitigation Volumes and Expenditure [CV9a, CV10]

Full mitigation of BT21CN is not driven by scheme volumes, i.e. not dependent on a target number of schemes being completed. BT21CN Mitigation can be completed with slightly more or fewer schemes, depending on costs of dark fibre links and the options available for strategic links that complete the (N-1) resilient fibre rings. However, scheme volumes are included in this business plan, representing the current understanding of how the fibre network will be deployed.

For the figures behind these graphs, refer to Appendix 5 NLRE Expenditure Plan.

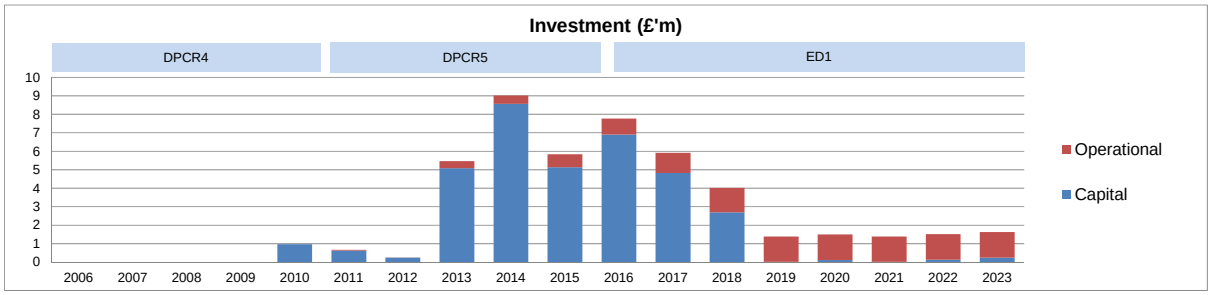


Figure 9 – BT21CN Mitigation investment (£m)

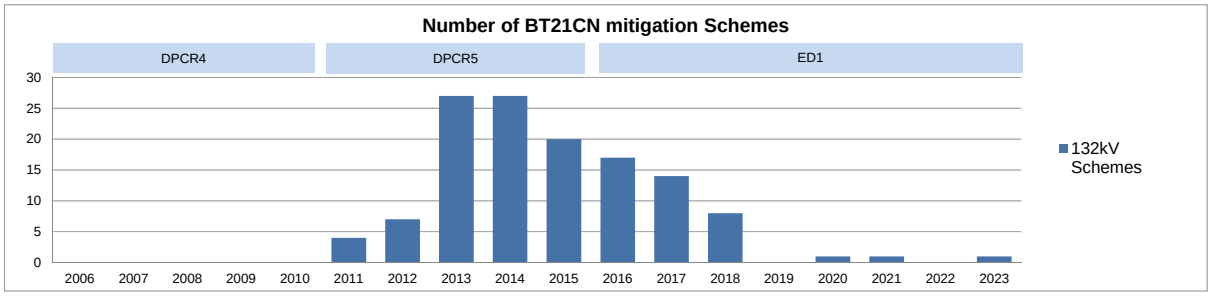


Figure 10 – BT21CN Mitigation scheme volumes

7.5 Commentary

7.5.1 The FBPQ submission

The FBPQ submission by UK Power Networks for the EPN BT21CN Mitigation programme forecast a requirement of £34.3m in DPCR5 to install optical fibre links. This forecast contained the following:

- 70 schemes to be done in DPCR5
- 44 schemes which had no DPCR5 forecast requirements as they were programmed for deployment in the following regulatory period (now known as ED1).

The allowance provided by Ofgem for DPCR5 was £28.7m.

7.5.2 DPCR5 forecast

The forecast for DPCR5 is to complete 85 schemes at a capital cost of £19.7m, with an average of £232k per scheme. A further £1.6m of operational costs is also forecast for DPCR5, which comprises mostly of rental costs of third party leased dark fibre links.

The composition of the schemes is as follows:

- 65 of these are from the original 70 schemes programmed for DPCR5 in the FBPQ submission. Of the five schemes deferred to ED1, three have been deferred to achieve mobilisation and outage efficiencies by aligning with asset replacement projects, one has been deferred due to a diversion request on the overhead route which needs to be resolved prior to any fibre installation in order to avoid the need for re-investment in the event the overhead line is dismantled and diverted underground, and one has been deferred due to proposed strategic network changes which need to be confirmed before the resilience requirements of the route can be established. All the deferrals have been for reasons of cost efficiency and risk minimisation.
- 19 of these are from the 44 schemes that were programmed post-DPCR5 in the FBPQ submission, where subsequent updates to the programme have taken the opportunity to bring them forward to DPCR5. The reason for this is to mitigate the deferrals stated above, to align with asset replacement projects, and to prevent excessive delivery pressure on ED1 as it is apparent that new schemes are required to complete the programme.
- 1 of these was not listed in the FBPQ submission, but has been added in subsequent updates to the programme once its requirement became apparent.

As of Q1 2014, 54 schemes are completed or expecting imminent completion.

Also, there are 8 self build schemes currently at risk of non-delivery in DPCR5 due to outage issues, environmental consents, and dependencies on asset replacement plans. With regards to dark fibre schemes, the third party provider has a proven delivery track record thus far. However, with the high level of dark fibre delivery planned for late DPCR5, it is prudent to assume that a further 5 dark fibre schemes are at risk of delivery slip into ED1.

It must be noted that this forecast is subject to the sensitivities outlined in section 0. The same applies to ED1 delivery.

7.5.3 DPCR5 forecast versus FBPQ submission

In the DPCR5 forecast, there is a reduction in average cost per scheme compared to original allowance of 70 schemes at £28.7m (£410k per scheme). The main reason for this is the cost estimation process behind the FBPQ plan had little visibility of the extent of dark fibre possible for BT21. Discussions with third party fibre providers have since allowed for inclusion of dark fibre solutions in the plan, and analysis has shown it to be the most cost effective solution (over the whole life of 40 years) for many schemes that were originally planned for self build.

Considering three examples:

1. Rayleigh/Nevendon/Fleethall. In the FPBQ submission, these were planned for self-build solution in DPCR5 for £1.4m. However, whilst Rayleigh-Fleethall is currently underway for self-build delivery, Rayleigh-Nevendon has been amended to a low-capital dark fibre solution (via South Benfleet) based on a whole life cost analysis. In fact, the analysis took into account an entire group of schemes in the region (Rayleigh, S Benfleet, Nevendon, Basildon, Tilbury Tee, Shell, Coryton) and determined that the dark fibre solution would enable the most cost effective solution for that region over the 40 year analysis period. Hence, the DPCR5 forecast for this line is now reduced to £0.9m.

2. Lowestoft/Ilketshall/Trowse/Great Yarmouth line. The FBPQ plan was £3.8m for self-build deployment of fibre on overhead lines. Planning discussions with the third party fibre provider revealed that they have fibre routes in the area which run very close to these grid sites. The subsequent dark fibre prices

provided then rendered it to be the most cost effective option over the 40 year analysis period, hence reducing the DPCR5 forecast significantly to £0.36m. Similar outcomes were realised in Epping/Harlow West/Rye House, Barking/Crowlands, Melbourn/Pelham/Wymondley, and other routes.

3. Bramford/Wickham Market/Rumburgh line. The DPCR5 plan was £1.5m for self-build deployment of fibre on overhead lines. Subsequent surveys revealed that the third party fibre provider have earth wrap on those overhead lines, which provide a low-cost and fast delivery solution for BT21. Hence, the DPCR5 forecast has reduced to £0.41m. Similar outcomes were realised on the Elstree/Borehamwood/Barnet/Brimsdown routes.

Note that the level of dark fibre delivery results in a significant operational cost (rental) forecast commencing in DPCR5 and extending to ED1 and beyond. However, the whole life cost analysis takes into account this rental element for each scheme (or group of schemes) to ensure that the overall solution for BT21CN Mitigation is the most cost effective one over the 40 year period. (See section 5.2 for more details on the fibre deployment strategy).

7.5.4 ED1 forecast

The forecast for ED1 as presented in this business plan is to complete 42 schemes at a capital cost of £14.9m, with an average of £355k per scheme. A further £10.2m of operational costs is also forecast for ED1, which comprises mostly of rental costs of third party leased dark fibre links.

The composition of the schemes is as follows:

- 25 of these are from the 44 schemes that were programmed for post-DPCR5 in the FBPQ submission.
- 5 of these are from the 70 schemes programmed for DPCR5 in the FBPQ submission, which have subsequently been deferred to ED1 (see DPCR5 Forecast section above)
- 12 of these were not listed in the FBPQ submission, but have been added in subsequent updates to the BT21 programme once their requirement became apparent.

7.5.5 ED1 forecast versus DPCR5 forecast

The forecast average capital cost per scheme in ED1 is £355k, whereas that in DPCR5 is £232k.
The reason for the higher cost per scheme is that ED1 has a high proportion of self build schemes (27 of the 42 are self-build). Self-build schemes are capital intensive compared to dark fibre, but incur much lower operational costs. Also, many of the self-build schemes, like Bramford-Belchamp and Huntingdon-Corby, are very large ones.

7.5.6 ED2

The forecast for ED1 is a gradual reduction in scheme volumes and expenditure over 2016 to 2018, producing a fibre network that fully mitigates BT21CN by 2018.

Continued alignment beyond 2018 and into ED2 is expected and recommended to increase resilience on the network and reduce reliance on third-party leased fibre. In ED1, specific schemes have been identified with which alignment can take place. In ED2, specific schemes have not been identified, but a residual capital allowance is required to ensure any alignment opportunities are realised.

With delivery of the schemes and the level of dark fibre deployment expected, operational cost requirements will increase markedly and plateau in 2018, beyond which increases in operational costs will be minimal and solely caused by installation of fibre in alignment projects.

7.5.7 Comparison with SPN expenditure

The EPN expenditure levels are significantly higher than those in SPN because more substation-to-substation schemes need to be delivered in EPN to fully mitigate the risk of BT21CN.

7.6 Sensitivity Analysis and Plan Validation

7.6.1 Assumptions taken in the development of the BT21CN cost models

- The BT21 self-build fibre construction costs have been developed based on pricing provided in the 2012 programme and through consultation with equipment suppliers and contractors on resourcing and installation rates for the project. Therefore, it is assumed that these will be available.
- The BT21 leased dark fibre installation and rental costs are based on high-level costs, where obtained from the fibre network operator. Where high-level costs are not available, estimates based on route length are applied, pending a costing exercise by the fibre network operator.

The above assumptions apply to both the DPCR5 and ED1 forecasts.

7.6.2 Details of the forecast's sensitivity

For the recommended BT21CN Mitigation solution, the DPCR5 and ED1 project forecast is subject to the following sensitivities:

- Increase in costs or variation of spend profile due to the assumptions above not being correct.
- On-going development and assessment of all communication options may provide further cost reduction.
- Engineering difficulties, including traffic management of work sites and transport infrastructure crossings, may result in increased costs on self-build fibre projects.
- The BT21 self-build fibre and equipment costs are based on quotations from suppliers. Equipment costs and order lead time may be subject to change.
- Additional costs may be incurred on self-build fibre projects due to unforeseen land compensation and Wayleave payments.
- Additional costs may be incurred on leased dark fibre projects due to longer cabling works and capacity upgrades.
- Sections of the self-build fibre network are exposed to the environment and third-party interference, which may result in damage. Since this type of damage is difficult to predict, the costs allocated for maintenance and/or repair activities may vary.

- Before the commencement of each annual programme, a full feasibility study will be undertaken. The results of the studies may affect the chosen options in terms of highlighting more efficient solutions on particular links. It should also be noted that the progress of alignment projects and unforeseen network issues may affect the chosen solution as the project develops. Consequently, there may be a change to the forecast costs.

There is sensitivity to reduced alignment and overhead line condition; however these have been treated as risk and can be found in Appendix 8 Risk Assessments.

7.7 Deliverability

7.7.1 Network access and outage availability

Liaison is on-going with UK Power Networks' Outage Planning regarding all BT21 schemes, with a particular focus on those schemes planned for latter stages of the programme (2017 and 2018). This is to minimise the effect of outage withdrawals on those schemes in light of the 2018 deadline.

Where possible, fibre installation via alignment is carried out, minimising outage requirements on overhead routes.

7.7.2 Delivery volumes

BT21CN Mitigation is carried out as a series of calendar year programmes. UK Power Networks' EPN Capital Programme Delivery has confirmed that the annual volumes are deliverable, provided the required engineering, financial and contractual approvals are obtained prior to commencement of the calendar year. As this is the approach to be applied throughout the programme, the scheme volumes are considered deliverable.

Delays in the programme could increase pressure on contractor(s) and UK Power Networks' delivery, resulting in risk of non-completion by 2018. However, there is sufficient float in each year's programme to ensure that delayed schemes, if any, can be accommodated.

Appendices

Appendix 1 Age Profiles

Not relevant: intentionally left blank.

Appendix 2 HI Profiles

Not relevant: intentionally left blank.

Appendix 3 Fault Data

Not relevant: intentionally left blank.

Appendix 4 WLC Case Studies

Understanding whole life cost analyses

Whole life cost analysis factors both initial (year 0) capital expenditure along with subsequent expenditure over 40 years for maintenance of the fibre route to determine the cumulative NPV of the whole life cost.

The two graphs below illustrate the cumulative NPV curves over 40 years for two different BT21 schemes. Both schemes do not need resilience as they are part of a self-healing fibre ring, and both overhead routes are in suitable condition to be wrapped. Hence, the final four options are OPGW, OPPC, fibre wrap and single dark fibre pair with 10-year rental.

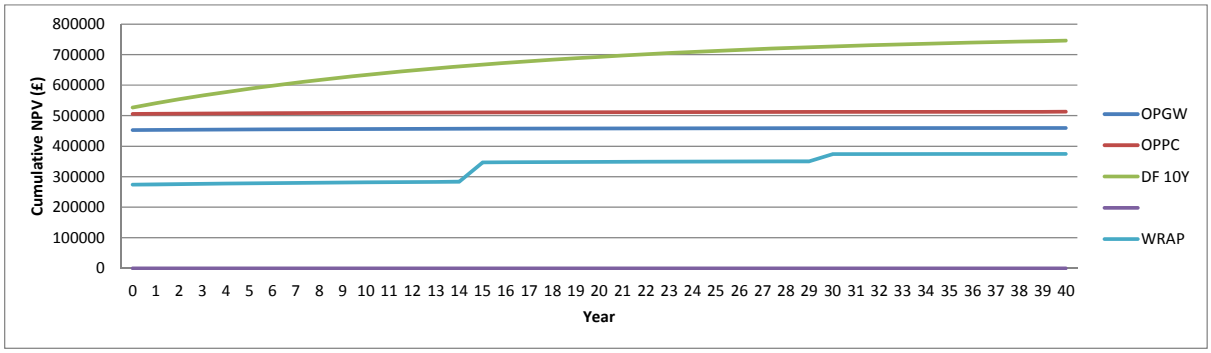


Figure 11 – Scheme 1: cumulative whole life cost

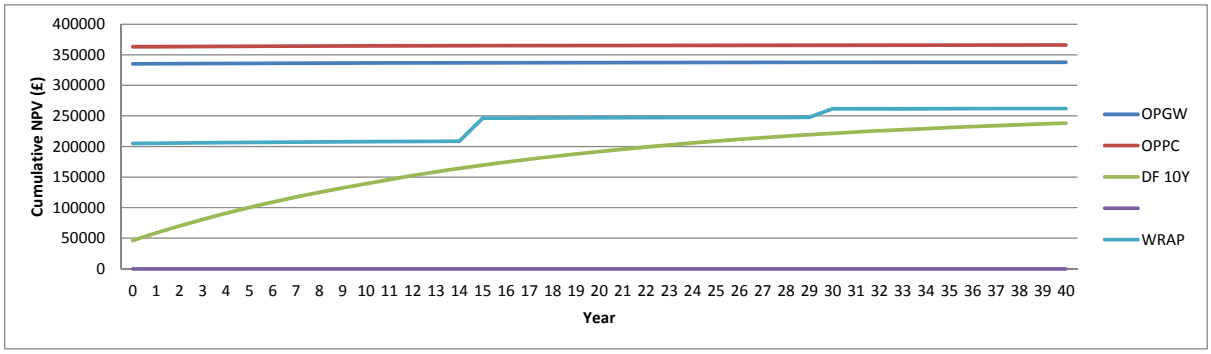


Figure 12 – Scheme 2: cumulative whole life cost

As expected, of the self-build options, OPPC is the most capital intensive (year 0), followed by OPGW and fibre wrap. Dark fibre installation costs depend heavily on the proximity of third-party fibre routes to UK Power Networks' grid sites.

OPPC and OPGW operational cost requirements are low, as expected, and hence there is very little increase in cumulative NPV over the 40-year analysis.

Fibre wrap has higher maintenance costs, but the primary contributor to the marked increase in cumulative NPV is the cost of re-wrapping the fibre every 15 years (years 15 and 30).

Dark fibre requires high rental costs in comparison to self-build maintenance costs, hence the significant rise in cumulative NPV over 40 years.

For a breakdown of the year 0 capital outlay and subsequent annual operational requirement for each option, refer to Table 8.

Composition of Year 0 capital expenditure of each option			
OPGW	**OPPC**	**Fibre Wrap**	**Dark Fibre**
Feasibility studies by contractor	Feasibility studies by contractor	Feasibility studies by contractor	High Level feasibility and costing, followed by detailed design, by third party fibre network owner
Installation by contractor	Installation by contractor	Installation by contractor	Installation cost by third party fibre network owner
Terminal tower to relay room cabling by contractor	Terminal tower to relay room cabling by contractor	Terminal tower to relay room cabling by contractor	Hand off point (usually substation wall) to relay room cabling by contractor
Wayleaves	Wayleaves	Wayleaves	Wayleaves
Environmental Costs	Environmental Costs	Environmental Costs	Environmental Costs
Internal Project Management and Design	Internal Project Management and Design	Internal Project Management and Design	Internal Project Management and Design
Other (vegetation clearance, line patrols, etc…)	Other (vegetation clearance, line patrols, etc…)	Other (vegetation clearance, line patrols, etc…)	n/a
Substation Building Fibre Works (Multiplexers and cabinets supply, splicing, and telecoms testing)	Substation Building Fibre Works (Multiplexers and cabinets supply, splicing, and telecoms testing)	Substation Building Fibre Works (Multiplexers and cabinets supply, splicing, and telecoms testing)	Substation Building Fibre Works (Multiplexers and cabinets supply, splicing, and telecoms testing)
Protection Commissioning	Protection Commissioning	Protection Commissioning	Protection Commissioning
Composition of annual opex of each option			
OPGW	**OPPC**	**Fibre Wrap**	**Dark Fibre**
General Maintnance of £0.0266 per metre	General Maintnance of £0.0266 per metre	General Maintnance of £0.0266 per metre	Rental Cost of Dark Fibre as charged by third party network owner
Specific maintenance and testing of £0.0403 per metre	Specific maintenance and testing of £0.0436 per metre	Specific maintenance and testing of £0.1151 per metre	Testing costs of £250

Table 8 – Fibre solutions capital and operational cost compositions

A. Rayleigh – Fleethall

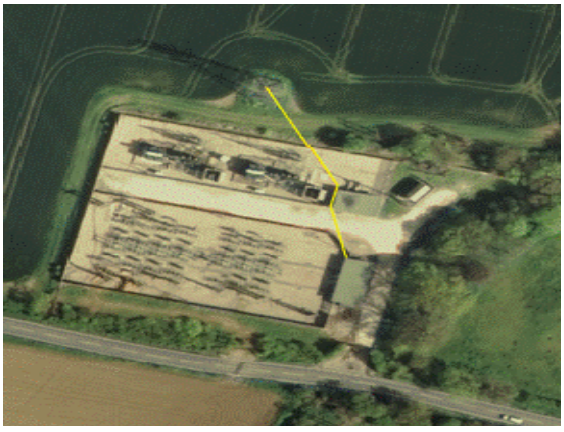
Desktop route study:

Site A	Route name	Site B	Terminal tower to site A	Nature of cabling route	OHL Distance	Terminal tower to Site B	Nature of cabling route
Rayleigh	PY	Fleethall	413m	NG shared site with fields, roads, crossings	16909m	63m	Simple dig to terminal tower

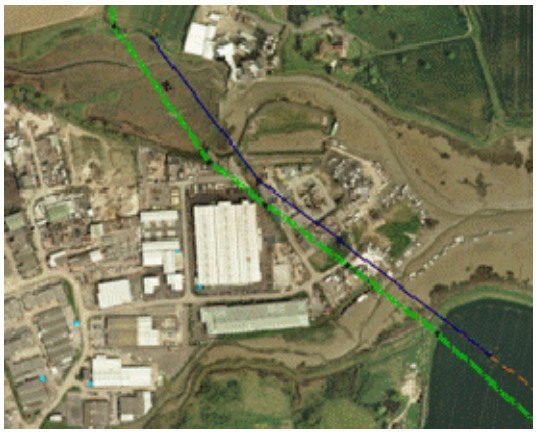
Number of towers	Minor crossings	Major crossings
56	9	11

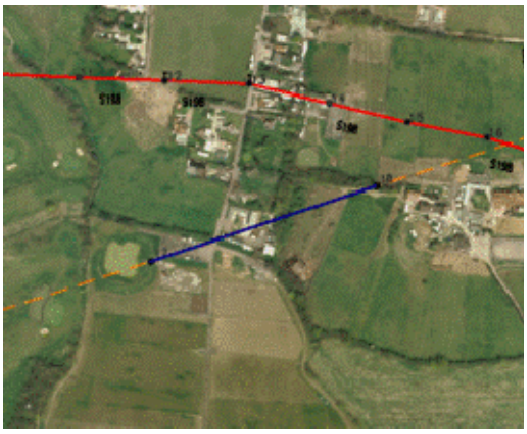
Terminal tower to relay room at Rayleigh

Terminal tower to relay room at Fleethall

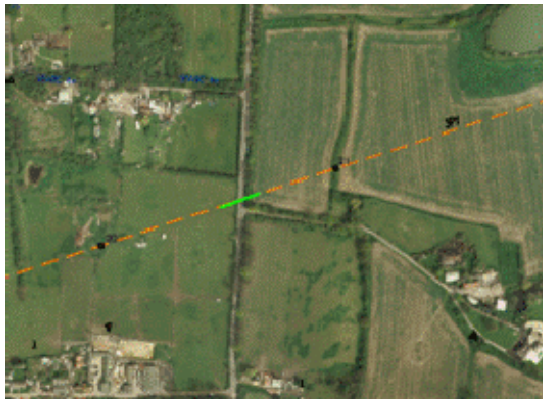


Examples of major crossings





Examples of minor crossings

Asset replacement programmes

There are no planned asset replacement programmes on this route with which fibre can be installed in alignment.

Condition data

Cormon test results

Circuit ID	Circuit route (from)	Circuit route (to)	Year tested	Span: from/to	Conductor type	Circuit	Condition point
PY	Rayleigh	Fleethall	2011	008-007	Lynx	Circuit 1	**1**
PY	Rayleigh	Fleethall	2011	008-007	Lynx	Circuit 1	**1**
PY	Rayleigh	Fleethall	2011	008-007	Lynx	Circuit 1	**1**
PY	Rayleigh	Fleethall	2011	008-009	Lynx	Circuit 1	**1**
PY	Rayleigh	Fleethall	2011	008-009	Lynx	Circuit 1	**1**
PY	Rayleigh	Fleethall	2011	008-009	Lynx	Circuit 1	**1**
PY	Rayleigh	Fleethall	2011	008-009	Lynx	Earth	**1**
PY	Rayleigh	Fleethall	2011	008-007	Lynx	Earth	**1**

Earth and phase conductors are condition 1. Hence, the OHL can be fibre wrapped on both the earth and phase conductors.

Dark fibre installation and rental costs

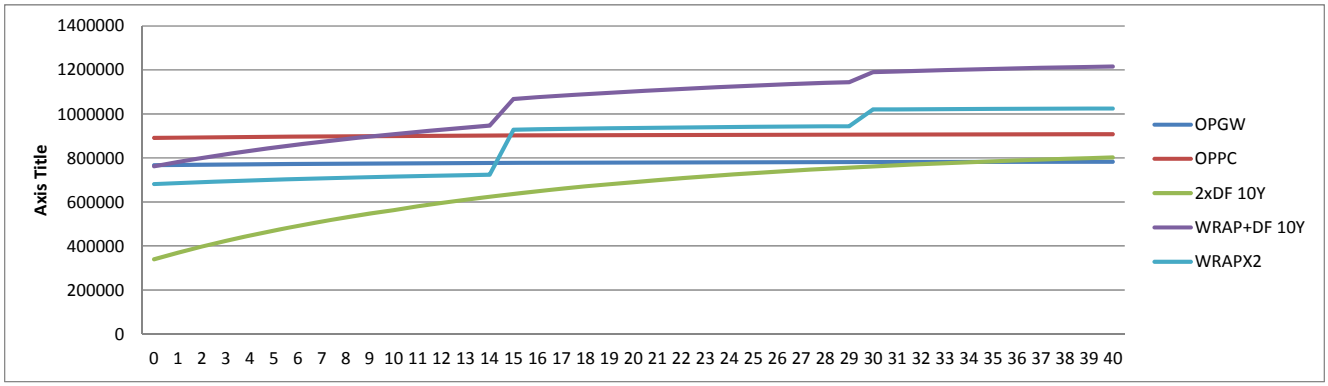
This is a spur route, therefore both single and two fully diverse dark fibre pairs are considered.

Installation		Rental 10Y		Rental 7Y		Rental 5Y	
Single pair DF installation	Two diverse pairs DF installation	Single pair rental	Two diverse pairs rental	Single pair rental	Two diverse pairs rental	Single pair rental	Two diverse pairs rental
£285,230	£300,053	£17,906	£31,330	£19,895	£34,827	£20,943	£36,650

Whole life cost analysis

For an understanding of the composition of the installation and operational costs below, refer to Table 8.

	Installation	Operational	NPV whole life cost
OPGW	£767,186	£1,131	£782,534
OPPC	£891,215	£1,187	£907,322
2xDF 10Y	£339,727	£31,580	£802,024
WRAP+DF 10Y	£762,343	£20,553	£1,215,211
WRAPX2	£681,379	£4,794	£1,024,817

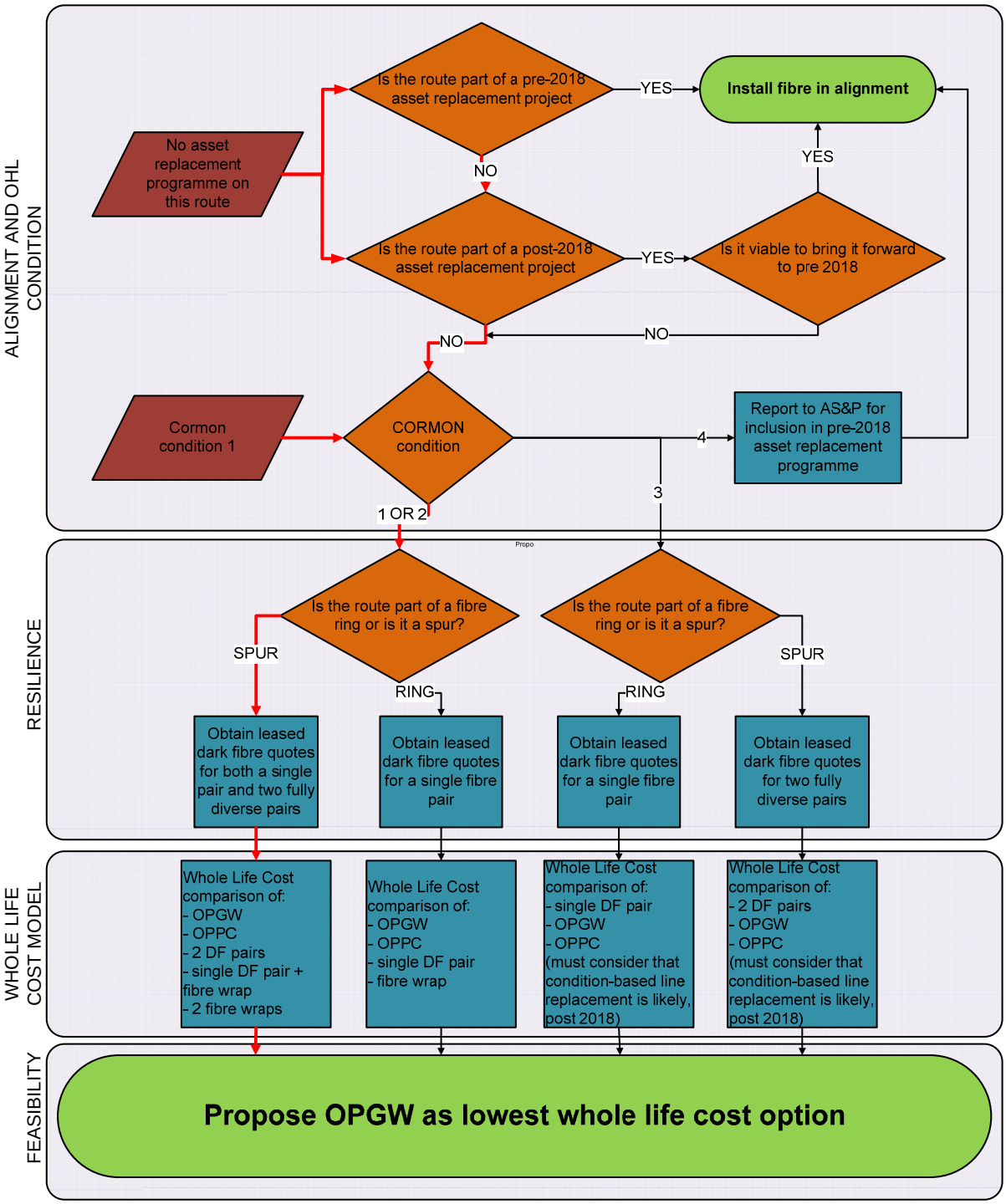


OPGW was identified as the lowest whole life cost, and recommended for feasibility study.

Options evaluation flowchart:

Red lines illustrate how the intervention evaluation process was applied to this scheme

Rayleigh – Fleethall scheme intervention flowchart



B. Colchester – Lawford

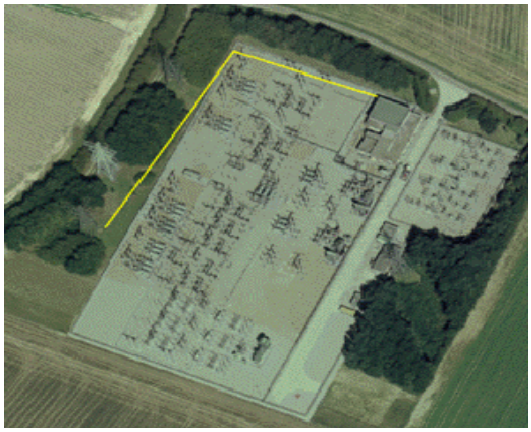
Desktop route study

Site A	Route name	Site B	Terminal tower to site A	Nature of cabling route	OHL distance	Terminal tower to site B	Nature of cabling route
Colchester	PNB	Lawford	34m	Simple dig to terminal tower	7576m	160m	Simple dig to terminal tower

Number of towers	Minor crossings	Major crossings
28	6	4

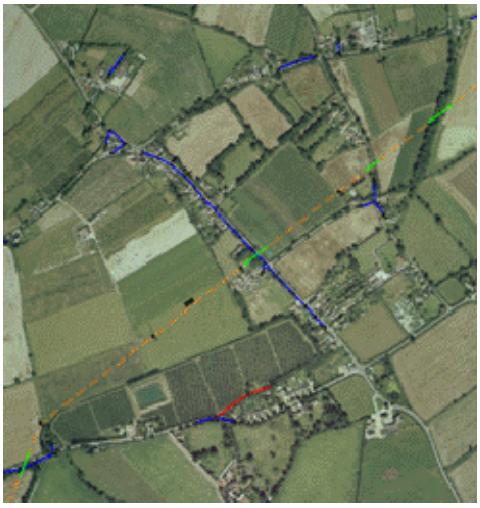
Terminal tower to relay room at Colchester

Terminal tower to relay room at Lawford



Examples of major crossings

Examples of minor crossings



Asset replacement programmes

There are no planned asset replacement programmes on this route with which fibre can be installed in alignment.

Condition data:

Cormon test results

Circuit ID	Circuit route (from)	Circuit route (to)	Year tested	Span: from/to	Conductor type	Circuit	Condition point
PNB	Lawford	Colchester	2011	006-005	Lynx	Circuit 2	**1**
PNB	Lawford	Colchester	2011	006-005	Lynx	Circuit 2	**1**
PNB	Lawford	Colchester	2011	006-005	Lynx	Circuit 2	**1**
PNB	Lawford	Colchester	2011	006-007	Lynx	Circuit 2	**1**
PNB	Lawford	Colchester	2011	006-007	Lynx	Circuit 2	**1**
PNB	Lawford	Colchester	2011	006-007	Lynx	Circuit 2	**1**
PNB	Lawford	Colchester	2011	006-005	Horse	Earth	**2**

Earth and phase conductors are condition two and one, respectively. Hence, the OHL can be fibre wrapped on both the earth and phase conductors.

Dark fibre Installation and rental costs

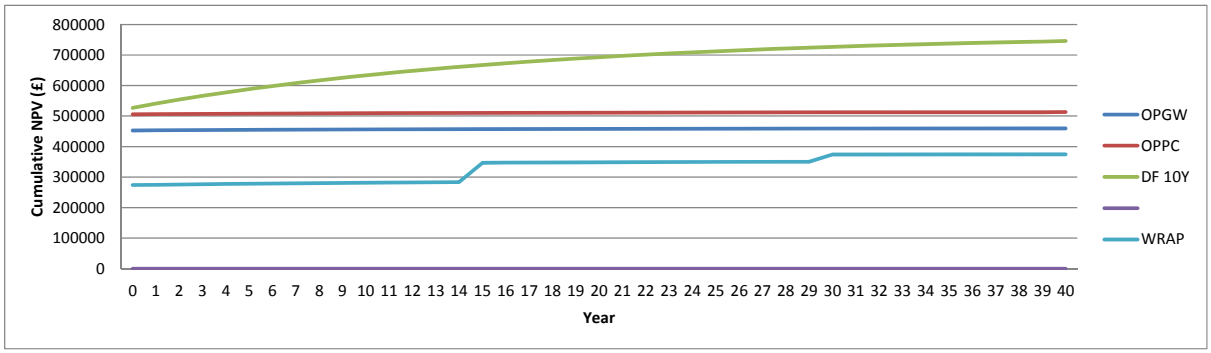
Ring route, therefore only single dark fibre pair considered.

Installation		Rental 10Y		Rental 7Y		Rental 5Y	
Single pair DF installation	Two diverse pairs DF installation	Single pair rental	Two diverse pairs rental	Single pair rental	Two diverse pairs rental	Single pair rental	Two diverse pairs rental
£489,784	n/a	£14,700	n/a	£15,473	n/a	£16,288	n/a

Whole life cost analysis

For an understanding of the composition of the installation and operational costs below, refer to Table 8.

	Installation	Operational	NPV whole life cost
OPGW	£452,718	£452,718	£459,594
OPPC	£505,612	£505,612	£512,828
DF 10Y	£526,998	£526,998	£745,704
WRAP	£274,101	£274,101	£374,828

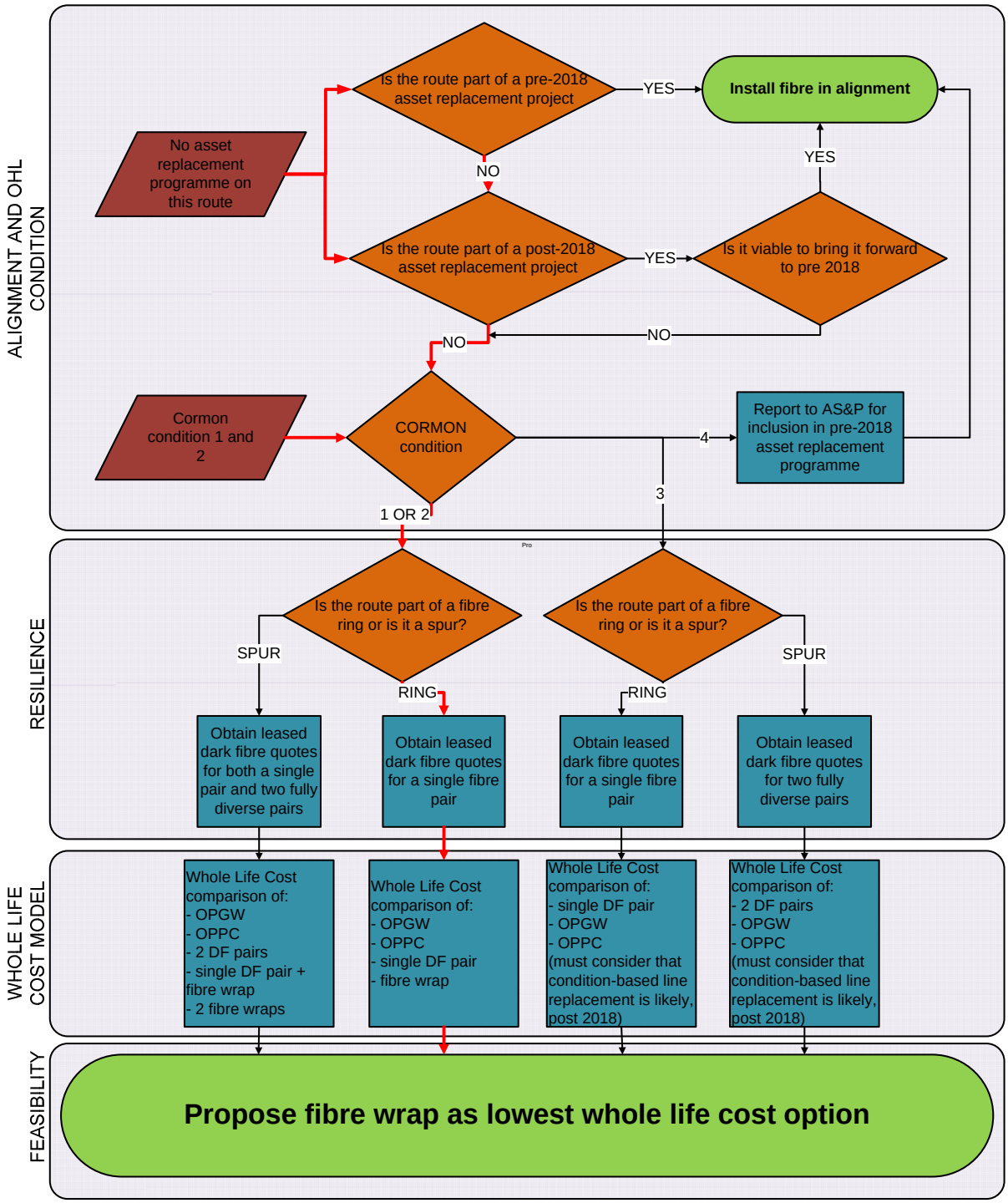


Fibre wrap was identified as the lowest whole life cost, and recommended for feasibility study.

Options evaluation flowchart:

Red lines illustrate how the intervention evaluation process was applied to this scheme

Colchester – Lawford scheme intervention flowchart



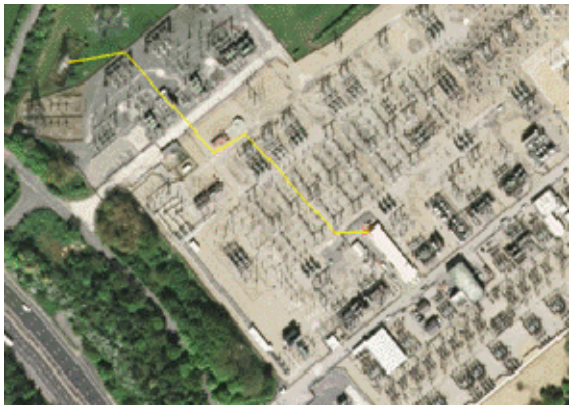
C. Elstree – Bushey Mill

Desktop route study

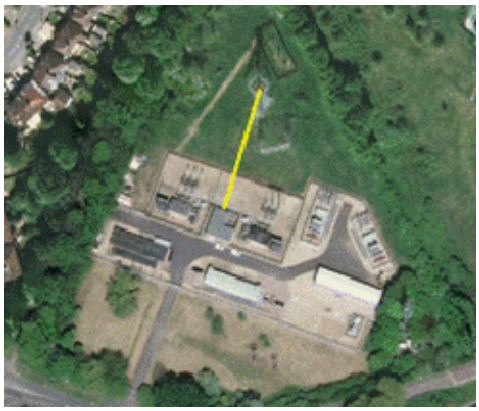
Site A	Route name	Site B	Terminal Tower to Site A	Nature of cabling route	OHL Distance	Terminal Tower to Site B	Nature of cabling route
Elstree	PKA	Bushey Mill	270m	NG shared site with simple dig	2918m	62m	Simple dig to terminal tower

Number of towers	Minor crossings	Major crossings
13	2	5

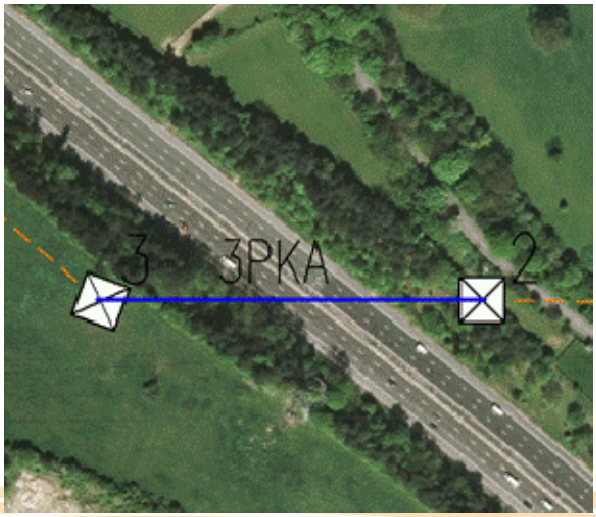
Terminal tower to relay room at Elstree

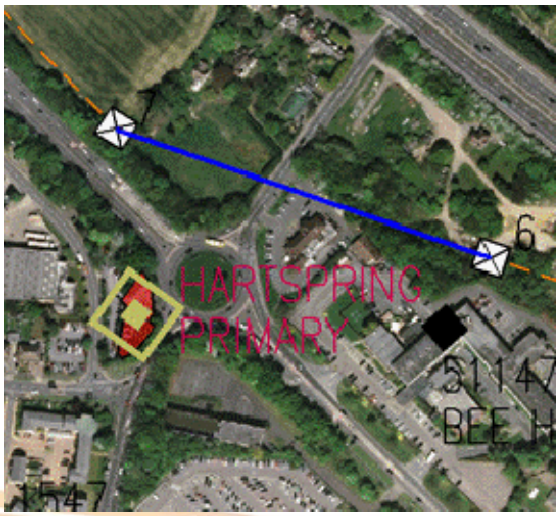


Terminal tower to relay room at Bushey Mill

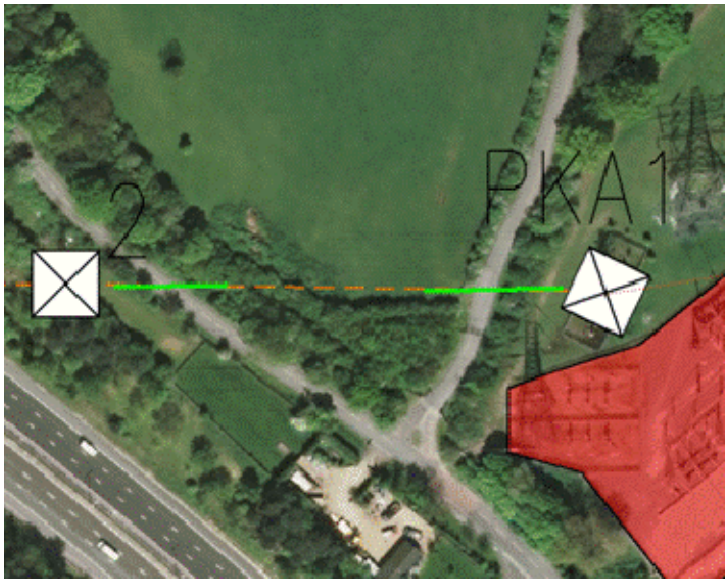


Examples of major crossings





Minor crossings



Asset replacement programmes

There are no planned asset replacement programmes on this route with which fibre can be installed in alignment.

Condition data

Cormon test results

Circuit ID	Circuit route (from)	Circuit route (to)	Year tested	Span: from/to	Conductor type	Circuit	Condition point
PKA	Elstree	Bushey Mill	2011	006-005	Zebra	Circuit 2	**1**
PKA	Elstree	Bushey Mill	2011	006-005	Zebra	Circuit 2	**3**
PKA	Elstree	Bushey Mill	2011	006-005	Zebra	Circuit 2	**1**
PKA	Elstree	Bushey Mill	2011	006-007	Zebra	Circuit 2	**1**
PKA	Elstree	Bushey Mill	2011	006-007	Zebra	Circuit 2	**1**
PKA	Elstree	Bushey Mill	2011	006-007	Zebra	Circuit 2	**1**

Phase wire cannot be fibre wrapped due to condition three.

Earth wire needs to be Cormon tested to determine the possibility of fibre wrapping. For purposes of options evaluation, assume fibre wrap on earth wire is an option.

Dark fibre installation and rental costs

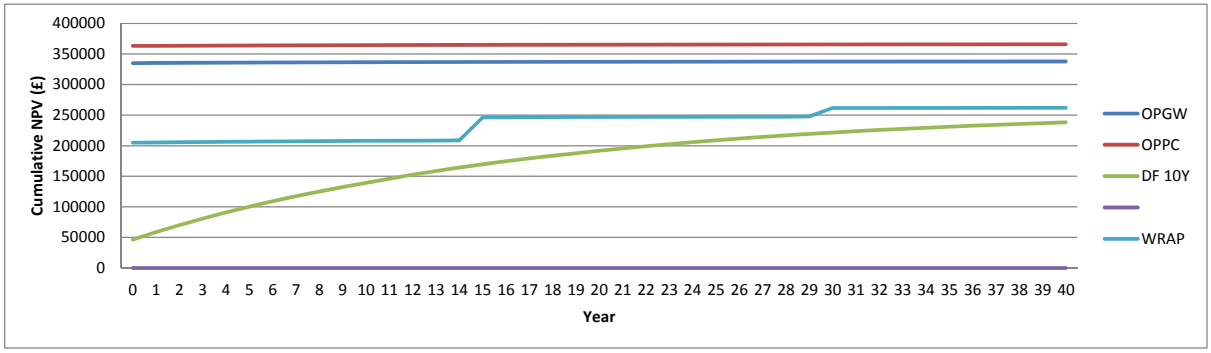
Ring route, therefore only single dark fibre pair considered.

Installation		Rental 10Y		Rental 7Y		Rental 5Y	
Single pair DF installation	Two diverse pairs DF installation	Single pair rental	Two diverse pairs rental	Single pair rental	Two diverse pairs rental	Single pair rental	Two diverse pairs rental
£6,702	N/A	£12,861	N/A	£13,538	N/A	£14,250	N/A

Whole life cost analysis

For an understanding of the composition of the installation and operational costs, refer to Table 8.

	Installation	Operational	NPV whole life cost
OPGW	£335,138	£195	£337,786
OPPC	£363,017	£205	£365,797
DF 10Y	£46,376	£13,111	£238,143
WRAP	£204,969	£414	£261,978

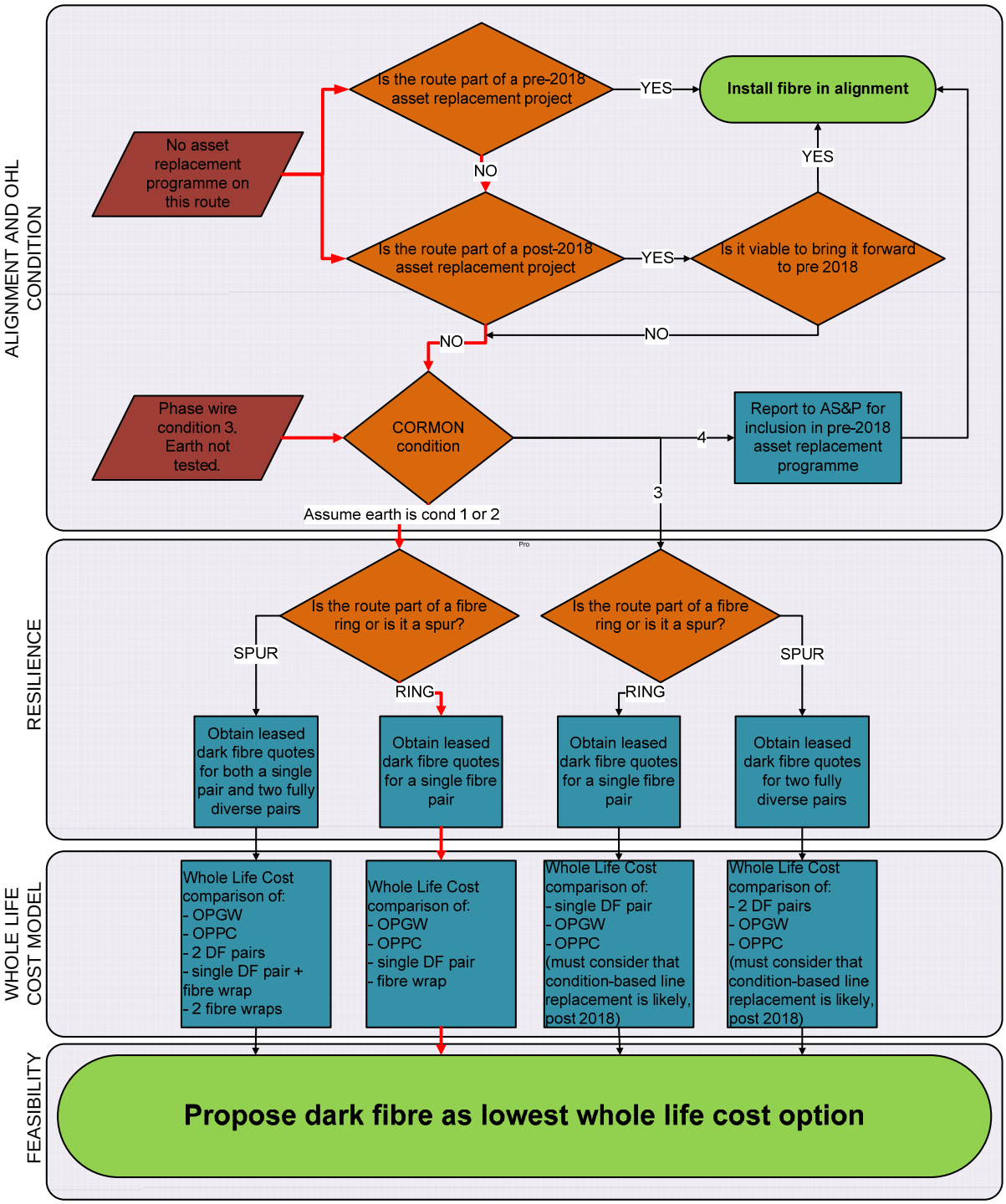


Dark fibre with 10-year rental contract was identified as the lowest whole life cost, and recommended for feasibility study.

Options evaluation flowchart

Red lines illustrate how the intervention evaluation process was applied to this scheme.

Elstree - Bushey Mill scheme intervention flowchart



Appendix 5 NLRE Expenditure Plan

Number of schemes

No. of BT21 Schemes	DPCR4					
Year end	2006	2007	2008	2009	2010	Total
132kV Schemes	0	0	0	0	0	0
33kV Schemes	0	0	0	0	0	0

No. of BT21 Schemes	DPCR5					
Year end	2011	2012	2013	2014	2015	Total
132kV Schemes	4	7	27	27	20	85
33kV Schemes	0	0	0	0	0	0

No. of BT21 Schemes	ED1								
Year end	2016	2017	2018	2019	2020	2021	2022	2023	Total
132kV Schemes	17	14	8	0	1	1	0	1	42
33kV Schemes	0	0	0	0	0	0	0	0	0

Expenditure

BT21 Investment (£'m)	DPCR4					
Year end	2006	2007	2008	2009	2010	Total
Capital	0.0	0.0	0.0	0.0	1.0	1.0
Operational	0.0	0.0	0.0	0.0	0.0	0.0

BT21 Investment (£'m)	DPCR5					
Year end	2011	2012	2013	2014	2015	Total
Capital	0.6	0.2	5.1	8.6	5.1	19.7
Operational	0.0	0.0	0.4	0.4	0.7	1.6

BT21 Investment (£'m)	ED1								
Year end	2016	2017	2018	2019	2020	2021	2022	2023	Total
Capital	6.9	4.8	2.7	0.0	0.1	0.0	0.1	0.2	14.9
Operational	0.9	1.1	1.3	1.4	1.4	1.4	1.4	1.4	10.2

Appendix 6 Sensitivity analyses

The forecast programme and cost sensitivities are non-calculable, except for the sensitivity to Overhead Line condition and Asset Replacement Programmes; these have been treated as risk and can be found in Appendix 8 Risk Assessments.

Appendix 7 Named Schemes

Case studies of named schemes are found in Appendix 4 WLC Case Studies.

Appendix 8 Risk Assessments

Overhead line condition

For each 132kV BT21 scheme, a high-level options evaluation has been carried out as described in section 5.2. This process only highlights the most likely fibre solution for the scheme.

Where recent (less than six years old) Cormon data is not available, existing data is used. Therefore, if it is judged to be condition one or two, the scheme might be evaluated to be a fibre wrap solution. Nevertheless, there exists a risk that fibre wrap will not be feasible if a new Cormon test shows that line condition has unexpectedly deteriorated to condition three or four since the last test. Additional expenditure will then be required to deploy OPGW or dark fibre as alternatives. The schemes at risk have been identified and the total impact of the risk calculated.

As the project's goal is to fully mitigate all BT private wires by the end of 2017, the impact of unexpected overhead line condition in the 2015-2017 BT21CN programmes is analysed. The capital investment impact is calculated over 2015-2017 whilst the operational cost impact is extended over 10 years (the expected rental period for dark fibre).

	2015/16		2016/17		2017/18		ED1 TOTAL			
	Schemes at risk	Cost Impact	Schemes at risk	Cost Impact	Schemes at risk	Cost Impact	Schemes at risk	Cost Impact	Estimated Likelihood	Risk Exposure
CAPEX (£k)	8	£364	2	-£318	2	£646	12	£692	33%	**£228**

OPEX (£k)	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	Total Cost Impact	Estimated Likelihood	Risk Exposure
Cost impact of 2015/16 programme		£77	£77	£77	£77	£77	£77	£77	£77	£77	£77			£772		
Cost impact of 2016/17 programme			£65	£65	£65	£65	£65	£65	£65	£65	£65	£65		£651		
Cost impact of 2017/18 programme				£14	£14	£14	£14	£14	£14	£14	£14	£14	£14	£136		
Total Impact of ED1 programmes	£0	£77	£142	£156	£156	£156	£156	£156	£156	£156	£156	£79	£14	£1,559	33%	**£515**

Reduced alignment

Where fibre installation is already planned to take place in alignment with a scheduled asset replacement project, there is the risk that the project may be deferred or cancelled. For example, load-based asset replacement projects could be deferred if the investment driver (increase in generation or load) is expected to be delayed. In these situations, the BT21CN project will consider resilience requirements and deploy dark fibre, fibre wrap or OPGW where appropriate.

As the project's goal is to fully mitigate all BT private wires by the end of 2017, the impact of reduced alignment opportunities in the 2014-2017 BT21CN programmes is analysed. The capital investment impact is calculated over 2014-2017, and the operational cost impact is extended over 10 years (the expected rental period for dark fibre).

	2015/16		2016/17		2017/18		ED1 TOTAL			
	Schemes at risk	Cost Impact	Schemes at risk	Cost Impact	Schemes at risk	Cost Impact	Schemes at risk	Cost Impact	Estimated Likelihood	Risk Exposure
CAPEX (£k)	0	£0	1	£151	1	-£21	2	£130	25%	**£33**

OPEX (£k)	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	Total Cost Impact	Estimated Likelihood	Risk Exposure
Cost impact of 2015/16 programme		£0	£0	£0	£0	£0	£0	£0	£0	£0	£0			£0		
Cost impact of 2016/17 programme			£29	£29	£29	£29	£29	£29	£29	£29	£29	£29		£294		
Cost impact of 2017/18 programme				£15	£15	£15	£15	£15	£15	£15	£15	£15	£15	£149		
Total Impact of ED1 programmes	£0	£0	£29	£44	£44	£44	£44	£44	£44	£44	£44	£44	£15	£443	25%	**£111**

Appendix 9 Full Optimised Plan

ED1 BT21CN Mitigation is phased into calendar year programmes (Jan-Dec), so the plans presented below cover calendar years.

2014 programme

CORYTON GRID - CORYTON TEE
SHELL GRID - STH. BENFLEET
TILBURY LOCAL - SHELL GRID
WARLEY - HORNCHURCH GRID
WARLEY - PURFLEET
WARLEY - SHENFIELD
NEVENDON GRID - RAYLEIGH LOCAL
HADLEIGH ROAD - LAWFORD
WICKHAM MARKET GRID - WICKHAM MARKET TEE
ILKETSHALL - RUMBURGH
TROWSE GRID - ILKETSHALL
LOWESTOFT GRID - ILKETSHALL
BUSHEY MILL GRID - WATFORD SOUTH
SUNDON - WESTONING
LT BARFORD - HISTON via HUNTINGDON
HUNTINGDON - HISTON
PETERBOROUGH CENTRAL EAST - PETERBOROUGH NORTH
PETERBOROUGH POWER - PETERBOROUGH EAST
KINGS LYNN - KINGS LYNN SOUTH
KINGS LYNN SOUTH - HEMPTON

2015 programme

BRAMFORD - HADLEIGH ROAD
BURY - BURWELL
BRAMFORD - BELCHAMP GRID
TROWSE GRID - GORLESTON GRID / GT YARMOUTH GRID / GT YARMOUTH PS
TROWSE GRID - THORPE GRID
EARLHAM / SALL - HEMPTON
THAXTED - BELCHAMP TEE
UGLEY BR - THAXTED
RYE HOUSE - PDA TEE
WELWYN GRID - PDA TEE
HATFIELD GRID - PDA TEE
LT BARFORD - EATON SOCON
PETERBOROUGH CENTRAL - HUNTINGDON
PETERBOROUGH NORTH - BRETTON BR
PETERBOROUGH NORTH / STAMFORD - PETERBOROUGH CENTRAL
BRETTON BR - STAMFORD

PFG TEE - BOURNE

2016 programme

NEVENDON GRID - BASILDON
TILBURY LOCAL - BASILDON GRID
WARLEY - BASILDON
BARKING/CROWLANDS - BRIMSDOWN
RICKINGHALL JUNCTION - THETFORD GRID
STOWMARKET GRID - RICKINGHALL JUNCTION
RICKINGHALL JUNCTION - DISS GRID
MELBOURN - MILTON BR / FULBOURN
WELWYN GRID - STEVENAGE
EPPING GRID - CHELMSFORD NORTH
HARLOW WEST - BISHOPS STORTFORD
BEDFORD GRID - EDISON RD
LT BARFORD - EDISON ROAD
HISTON - ARBURY GRID

2017 programme

BRAINTREE GRID - PGF TEE
BR SPRINGFIELD - CHELMSFORD NORTH
RAYLEIGH LOCAL - CHELMSFORD EAST
CORBY - HUNTINGDON
CORBY - GRENDON GRID
GRENDON GRID - BEDFORD
BEDFORD GRID - ARA GRID
RAE - ARA GRID

2018 programme

No schemes programmed.

2019 programme

ARBURY GRID - MILTON BR (alignment with asset replacement scheme).

2020 programme

TILBURY LOCAL - SHELL GRID (alignment with asset replacement scheme).

2021 programme

No schemes programmed.

2022 programme

RAYLEIGH MAIN - MALDON GRID (alignment with asset replacement scheme).

Appendix 10 RIGs mapping for ED1 volumes and expenditure

Expenditure				ASR	RIGs								
Asset Type	Asset Name	RIGs Table	RIGs Row	Total	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	Total
BT21 Capital	BT21CN Mitigation (1.26.10) 2016-2018	CV10	6	14.42	6.90	4.82	2.69	0.00	0.00	0.00	0.00	0.00	**14.42**
	BT21CN Mitigation (1.26.10) 2019-2023	CV105	7	0.52	0.00	0.00	0.00	0.01	0.12	0.01	0.13	0.25	**0.52**
BT21 Operational	BT21: Operations, Maintenance and Monitoring of SDH Fibre Network (2.28.31)	CV10	7	10.18	0.87	1.09	1.32	1.38	1.38	1.38	1.38	1.38	**10.18**
Total				**25.12**	**7.76**	**5.92**	**4.01**	**1.39**	**1.50**	**1.39**	**1.51**	**1.63**	**25.12**

Volumes	Asset Stewardship reports										RIG Table									
Investment destription	NAMP Line	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	Total	RIG Table	RIG Row	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	Total
BT21CN Mitigation 2016-2018	1.26.10	17	14	8	0	0	0	0	0	39	CV10	6	17	14	8	0	0	0	0	0	**39**
BT21CN Mitigation 2019-2023	1.26.10	0	0	0	0	1	1	0	1	3	CV105	7	No volume reporting in CV105 row 7								**0**
BT21: Operations, Maintenance and Monitoring of SDH Fibre Network	2.28.31.6780	No volumes stated								0	CV10	7	85	102	116	124	124	125	125	126	**927**
Total		**17**	**14**	**8**	**0**	**1**	**1**	**0**	**1**	**42**			**102**	**116**	**124**	**124**	**124**	**125**	**125**	**126**	**966**

Note regarding operational volumes:
In this document, BT21 operational volumes are not stated in the narrative.
In the RIGs, BT21 operational volumes are given as number of schemes on which operational expenditure is required. This is an annual requirement for each delivered scheme, and hence the volume against it is expressed as a cumulative running total of the number of schemes delivered.