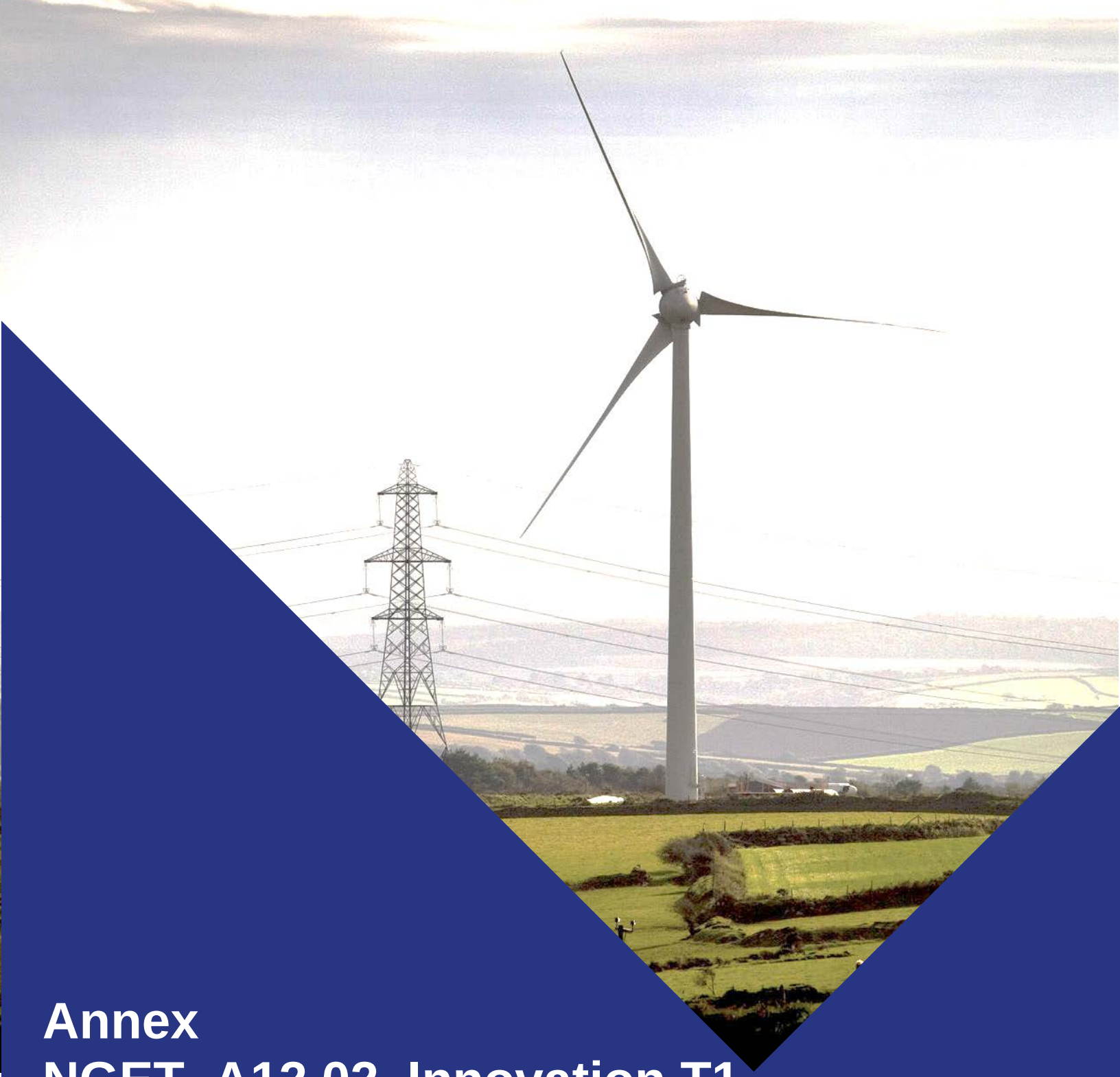

Annex NGET_A12.02_Innovation T1 Performance December 2019

As a part of the NGET Business Plan Submission

nationalgrid

RIIO-T2

nationalgrid
Electricity Transmission

NGET_A12.02_Innovation T1 Performance

Innovation
(December 2019)

Submission annex 2019

Contents

Summary

During T1 we have invested a total of £77.3m on innovation. We have also invested more than £34m in continuous improvement through business wide programmes which further improves and embeds our innovation culture. Our innovation investment is summarised in the following table:

Funding source	Number of Projects	Investment
NIA	161	£47.3m NIA
Deeside Centre of Innovation (NIC)	1	£10m NIC £14m NGET
GIL Innovation Partnership (Totex)	1	£3m Siemens £3m NGET (sanctioned)
Total	**163**	**£77.3m**

The total number of projects will increase by the end of T1 as we will continue to develop projects during the next year.

This Annex details our T1 performance by asset category:

Overhead Lines

Our Network Innovation Allowance (NIA) overhead line portfolio to date consists of 19 completed projects (totalling £8m), 4 ongoing projects (totalling £1.1m) and there are presently 6 proposals being developed which we expect to convert into projects in the coming months.

[TABLE I] below details the individual projects which compose this portfolio. The shaded projects are those which have contributed to the £192m of savings in T1 and £420m of savings in T2. Together, the outputs of these projects have led to modifications to our failure modes and effects curves and extensions to our technical asset lives for Aluminium Conductor Steel Reinforced (ACSR) conductors, insulators, spacers and dampers. These changes are implemented through the creation of technical reports, updates to our policy statements and technical guidance notes resulting in deferred conductor replacement in our capital plans and optimisation of our fittings investment through targeting work and reducing investment.

Some of these projects have also delivered environmental benefits through the introduction of new low-noise and more visually appealing overhead line solutions.

The outputs of the ‘ongoing’ projects as well as those still under development are longer-term projects, may not be successful and will not conclude in T1. The outputs from these projects do have potential to provide consumer benefits in our T2 plans but we will not know the extent of this until the projects are completed and we can understand how these outputs can be used to provide benefits in our T2 business plans.

Over T1 to date, through the EPRI Research Collaboration in overhead lines we have leveraged our spend with other international transmission owners in 5 of these projects spending £2.8m and gaining the outputs from £48.3m of innovation. This collaboration also enables acceleration of the pace of delivering learning and outputs due to an increase in testing and greater experience being recorded internationally.

It is worth noting the composite cross-arm study was funded jointly with SHET during the previous regulatory period (TPCR4). The NIA spend shown here is the spend T1.

TABLE I NIA PORTFOLIO OF PROJECTS FOR OVERHEAD LINE TRANSMISSION (COMPLETED, ONGOING AND IN IDEAS STAGE)

#	Name of Project	NIA Reference	NIA Spend (£k)	Leveraged Project Spend (£k)
Completed Projects				
1	Noise Assessment of ACCR Conductor	NIA_NGET0137	1,091.2	
2	Detection and Measurement of ACSR Corrosion	NIA_NGET0011	75.7	
3	Composite Cross-Arms Study	NIA_NGET0024	182.5	
4	Long Term Performance of Silicon Based Composite Insulators	NIA_NGET0035	76.1	
5	Live Line Working Equipment	NIA_NGET0043	370.5	
6	Trial & Performance Assessment of ACCR Conductor (3M)	NIA_NGET0067	26.3	
7	EPRI Research Collaboration on Overhead Circuits.	NIA_NGET0126	306.5	5,646.1
8	OHL Condition Assessment	NIA_NGET0140	223.0	
9	T-pylon Structure and Composite Insulator Testing	NIA_NGET0141	2,648.0	
10	Investigation of Aeolian Insulator Noise	NIA_NGET0149	98.3	
11	EPRI Research Collaboration on Overhead Transmission Lines Project	NIA_NGET0158	16.8	9,842.5
12	Evaluation of a Novel Variant of ACCC HTLS Conductor	NIA_NGET0164	317.6	
13	EPRI Research Collaboration on Overhead Transmission Lines Project	NIA_NGET0173	237.2	1,486.2
14	Classification of Wind Exposed Overhead line spans	NIA_NGET0181	244.2	
15	EPRI Research Collaboration on Overhead Lines 2016 (P35)	NIA_NGET0196	331.2	1,541.2
16	Development of fittings analysis model	NIA_NGET0197	228.2	
17	Cost effective removal of conductor crossing clearance constraints	NIA_NGET0198	276.0	
18	Novel methodology for assessing environmental exposure of OHL routes	NIA_NGET0206	966.0	
19	EPRI Research Collaboration on Overhead Lines (P35) 2017	NIA_NGET0209	303.1	7,450.0
Ongoing Projects				
20	Automated assessment of steelwork condition using innovative imaging techniques	NIA_NGET0215	251.8	
21	EPRI Research Collaboration on Overhead Lines (P35) 2018-2021	NIA_NGTO003	549.7	23,800.0
22	Predicting Vibration Fatigue for Overhead Line Conductor Systems	NIA_NGTO013	60.4	
23	Advanced Line Rating Analysis (ALiRA)	NIA_NGTO014	233..3	
Project Ideas				
24	Upgrading 275kv circuits to 400kv using insulated cross arms			
25	Non-intrusive conductor condition assessment			
26	Raising the height on in service OHL towers			
27	Non-intrusive tower foundation inspection techniques			
28	Environmental exposure of OHLs			
29	Dynamic Line Rating			

Transformers

Our NIA transformers portfolio consists of 12 completed projects (totalling £3.5m), 5 ongoing projects (totalling £4.2m) and there are presently 10 proposals being developed which we expect to convert into projects in the coming months.

[TABLE II] below details the individual projects which compose this portfolio. The shaded projects are those which have contributed to £238m of savings in T1 and £100m of savings in T2. Together, the outputs of these projects have led to modifications to our failures modes and effect curves and extensions to our technical lives of transformers by improving our understanding of transformer degradation and design weaknesses. These changes are implemented through the creation of technical reports, updates to our policy statements and technical guidance notes resulting in deferred transformer interventions in our capital plans.

The project titled, '400kV Synthetic Ester Filled Transformer Pilot Project', also led to the installation of the first 400kV synthetic ester-filled transformers at Highbury substation, delivering improved safety and environmental performance. This project was the result of 13 years of innovation projects funded through previous regulatory periods.

The outputs of the 'ongoing' projects as well as those still under development are longer-term projects, may not be successful and will not conclude in T1. The outputs from these projects do have potential to provide consumer benefits in our T2 plans but we will not know the extent of this until the projects are completed and we can understand how these outputs can be used to provide benefits in our T2 business plans. For example, we are focussing one of these projects to manage the challenges we face around how to manage spares where the original equipment manufacturer is no longer trading to help deliver maintenance and transformer bushing replacement programmes.

Over T1 to date, through the EPRI Research Collaboration and the Transformer Research Consortium, we have leveraged our spend with other international transmission owners in 5 of these projects spending £1.8m and gaining the outputs from £30m of innovation. This collaboration enables lessons learnt and outputs to be delivered more quickly due to increased experience internationally.

The Transformer Research Consortium is a highly-regarded international consortium of partners for transformer research at the University of Manchester. Under NIA, Phase 3 of the Transformer Research Consortium was funded jointly with Scottish Power Energy Networks (SPEN) and UK Power Networks (UKPN) through NIA with additional funding from Weidmann Electrical Technology, Royal Dutch Shell, M&I Materials and TJH/2b. Phase 4 of the consortium ('Transformer and Transformer Oil Life Optimisation and Management Through Analysis and Modelling') is ongoing and is co-funded by SPEN through NIA with equal shares also being contributed by EPRI, Weidmann Electrical Technology, Royal Smit Transformers, Royal Dutch Shell, Cargill, M&I Materials and TJH2b. This project also receives leveraged funding from TDHVL at the University of Southampton.

TABLE II NIA PORTFOLIO OF PROJECTS FOR TRANSFORMERS (COMPLETED, ONGOING AND IN IDEAS STAGE)

#	Name of Project	NIA Reference	NIA Spend (£k)	Leveraged Project Spend (£k)
Completed Projects				

1	400kV Synthetic Ester Filled Transformer Pilot Project	NIA_NGET0080	238.6	
2	Transformer & System Reliability	NIA_NGET0014	88.8	
3	Magnetic Models for Transformers	NIA_NGET0040	330.8	
4	Transformer Oil Passivation and Impact of Corrosive Sulphur (TOPICS)	NIA_NGET0044	357.2	
5	Transformer Research Consortium	NIA_NGET0088	307.1	1,050.0
6	EPRI Research Collaboration on Substations	NIA_NGET0123	285.2	1,148.6
7	Condition Monitoring of Power Assets (COMPASS)	NIA_NGET0147	68.3	
8	EPRI Research Collaboration on Substations	NIA_NGET0157	17.1	2,100.0
9	Transformer Rating Modelling Tool Enhancement (TeRMiTE)	NIA_NGET0165	503.7	
10	EPRI Research Collaboration on Substations	NIA_NGET0172	286.2	1,662.5
11	EPRI Research Collaboration on Substations 2016 (P37)	NIA_NGET0195	283.4	1,215.1
12	Thermal Efficiency Trials	NIA_NGET0099	719.9	
Ongoing Projects				
13	Development of a Universal Bushing	NIA_NGET0202	139.5	
14	Frequency Response Analysis for Transformer Characterisation and Objective Interpretation of Results	NIA_NGET0204	230.2	340.0
15	EPRI Research Collaboration on Substations (P37) 2017 - 2020	NIA_NGET0210	1,786.0	23,800.0
16	Condition and Climatic Environment for Power Transformers (ConCEPT)	NIA_NGET0213	1,044.5	
17	Transformer and Transformer Oil Life Optimisation and Management Through Analysis and Modelling	NIA_NGET0214	1,034.0	2,237.0
Project Ideas				
18	Efficient ageing of transformers (EAT)			
19	Barrier Board Condition Monitoring			
20	Power Electronic Enabled Transformers (PEETs)			
21	Lifetime performance of DGA monitors			
22	Statnett GIC project			
23	Fire damage zones			
24	Visual markers for switch oil			
25	Heat recovery, storage and energy conversion			
26	Development of hydraulic linear actuator assessment methodology			
27	New online tools for assessment of bushing condition			

Protection and Control

Our NIA Protection and Control portfolio consists of 12 completed projects (totalling £2.6m), 4 ongoing projects (totalling £0.6m) and there are presently 3 proposals being developed which we expect to convert into projects in the coming months.

[TABLE III] below details the individual projects which compose this portfolio. The shaded projects are those which have contributed to £192m of savings in T1 and £63m of savings in T2.

Together the outputs of these innovation projects, in conjunction with outputs from projects completed in the previous price control, led us to writing new technical specifications. The outputs have also provided us with the evidence to extend our technical lives of 3 of our relay types and develop our understanding of how the components within the protection system degrade. These changes are implemented through updating one of our technical reports, updates to our policy statements and technical guidance notes resulting in a targeted replacement intervention approach.

We have 4 projects in the area of cyber security and communications which come under the Protection and Control innovation portfolio. The knowledge from these projects help us design and maintain the security of our network and provides us with valuable insights to manage legacy equipment.

The outputs from the ongoing projects as well as those under development are focused on improving our resilience from external threats. For this reason, the outputs of these projects are unlikely to provide savings in T1 or T2 timescales.

Over T1, in a similar manner to transformers, through the EPRI Research Collaboration we have leveraged our spend with other international transmission owners in 2 of these projects spending £0.43m and gaining the outputs from £6.8m of innovation. In the area of cyber security, it has allowed us to develop and improve our policies.

TABLE III NIA PORTFOLIO OF PROJECTS FOR PROTECTION AND CONTROL (COMPLETED, ONGOING AND IN IDEAS STAGE)

#	Name of Project	NIA Reference	NIA Spend (£k)	Leveraged Project Spend (£k)
Completed Projects				
1	Reliability Assessment of System Integrity Protection Schemes (SIPS)	NIA_NGET0019	80.8	
2	Design of a smart tool for detecting hidden errors in protection setting files	NIA_NGET0038	140.0	
3	Alternative Bus Bar Protection Solution	NIA_NGET0064	38.5	
4	Alternative Differential Unit Protection for Cable only and Cable & OHL hybrid installations	NIA_NGET0072	4.5	
5	Proof of Concept for IEC61850 Process Bus Technology	NIA_NGET0104	124.1	
6	Assessment of Electronic (analogue and Numeric) Protection equipment end of life mechanisms	NIA_NGET0146	331.3	
7	Digital Substation – Virtual Site Acceptance Testing & Training	NIA_NGET0162	384.7	
8	A New Independent Methodology For P&C Coordination Studies Using Real Time Digital Simulation	NIA_NGET0168	451.9	
9	Feasibility study on suitability of protection policy for future energy scenarios	NIA_NGET0182	278.4	
10	Security Assessment of Industrial Control Systems (ICS)	NIA_NGET0189	244.6	
11	EPRI Research Collaboration on Cyber Security 2016 (P183)	NIA_NGET0190	207.3	2,123.8

Ongoing Projects				
12	**EPRI Research Collaboration on Information and Communication Technology (P161)**	**NIA_NGTO005**	**272.0**	**4,724.4**
13	Travelling Wave Fault Locator Trial	NIA_NGET0179	107.8	
14	IEC 61850 Cyber Resilient Electric Substation Technologies	NIA_NGTO020	336.0	
15	Substation Time Synchronisation to Safeguard the Network	NIA_NGTO025	50.7	
16	Assessment of Wireless Technologies in a Substation Environment	NIA_NGTO029	120.5	
Project Ideas				
17	Inter substation Process Bus			
18	Wide Area Monitoring Protection and Control			
19	Single hardware platform PAC system			

Underground Assets

Our NIA underground assets portfolio consists of 23 completed projects (totalling £4.5m), 4 ongoing projects (totalling £3.3m) and there are presently 5 proposals being developed which we expect to convert into projects in the coming months.

The outputs of the completed projects will not provide cost savings in T1 or T2.

The outputs of the ongoing projects as well as those still under development are longer-term projects, and will not be ready in time to change transformer interventions in T1. The outputs from these projects do have potential to provide consumer benefits in our T2 plans but we will not know the extent of this until the projects are completed and we can understand how these outputs can be used to provide benefits in our T2 business plans. For example, we are focussing one of these projects to test and trial a new backfill which will allow us to, in some instances, half the number of cables we need to install. We also have a large programme of work to understand HVDC cable technologies across their lifetime.

Over T1 to date, through the EPRI Research Collaboration, we have leveraged our spend with other international transmission owners in 2 of these projects spending £1.3m and gaining the outputs from £5.6m of innovation. This collaboration enables lessons learnt and outputs to be delivered more quickly due to increased experience internationally.

TABLE IV NIA PORTFOLIO OF PROJECTS FOR UNDERGROUND TRANSMISSION (COMPLETED, ONGOING AND IN IDEAS STAGE)

#	Name of Project	NIA Reference	NIA Spend (£k)	Leveraged Project Spend (£k)
Completed Projects				
1	Dinorwig Thermal Cycling and Cable Rating	NIA_NGET0015	362.4	
2	Cable Installation Design & Innovation Project (CIDIP)	NIA_NGET0087	248.2	
3	Cable Extraction	NIA_NGET0090	151.3	
4	EPRI Research Collaboration on Underground Transmission	NIA_NGET0150	87.0	230.0
5	Investigation into the Properties and Behaviour of Liquid Soil (LS) Technology	NIA_NGTO024	101.3	

6	Thermo-Mechanical Forces in XLPE Cable	NIA_NGET0036	291.7	
7	Cables with Long Electrical Sections	NIA_NGET0048	398.7	
8	Partial Discharge on Existing HV Cable	NIA_NGET0092	315.5	
9	Online Gas in Oil Analysis on Existing HV Cables	NIA_NGET0093	360.1	
10	Computer Vision for Cable Tunnels	NIA_NGET0098	30.9	
11	Modelling the tape corrosion process for oil-filled underground cables	NIA_NGET0103	463.5	
12	Cable Stripping Truck	NIA_NGET0115	55.0	
13	Impact of Seabed Properties on Ampacity and Reliability of Cables (ICASE Award)	NIA_NGET0136	92.0	300.0
14	CSE fault analysis by 3D monitoring	NIA_NGTO015	47.1	
15	Health Monitoring of cables using Acoustic Emission Measurement Techniques	NIA_NGTO026	61.4	
16	Oil/Paper Insulation HVDC Performance	NIA_NGET0017	104.5	
17	Flexible rating options for DC operation	NIA_NGET0046	206.4	
18	Load cycling and radial flow in mass impregnated HVDC Submarine cables	NIA_NGET0054	252.9	
19	Partial discharge monitoring of DC cable (DCPD)	NIA_NGET0073	138.9	
20	Impact of HVDC Cable Operation on Telecommunication Lines	NIA_NGET0089	68.5	
21	Dynamic Ratings for improved Operational Performance (DROP)	NIA_NGET0047	262.2	
22	Rating Impact of Non-Isothermal Ground Surface (RINGS)	NIA_NGET0082	69.7	
23	Smart Geo Grid	NIA_NGTO027	54.5	
Ongoing Projects				
24	EPRI Research Collaboration on Underground Transmission 2018 - 2021	NIA_NGTO028	1,587.9	5,456.7
25	Novel O-ring Designs (NORD)	NIA_NGTO032	316.4	
26	Electrical Characterisation of Silicone Oil (ECOSO)	NIA_NGTO009	607.2	
27	Liquids for cable sealing ends (LiCaSE)	NIA_NGTO010	1,050.3	
Project Ideas				
28	Big Data for Cable Systems			
29	Interpretation of PD from treeing defects in AC XLPE			
30	Tunnel Inspections and Machine Learning			
31	Cable oversheath materials and asset life			
32	Machine learning for backfills			

We also undertook a joint project with Siemens via an innovation partnership defined under the Public Procurement Directive to research and trial Gas Insulated Line (GIL) innovative technology as a viable alternative to underground cable, with the goal of reducing the whole-life cost and visual impact of underground transmission for consumers. To date, this partnership has reduced the projected cost of manufacturing and deploying GIL by a projected ~£3.5m/km. Despite these large strides forward, the environmental impact of SF6 is such that we have decided to terminate the partnership as we wish to focus on clean air technologies in line with our net zero target and these align with our NIA proposals for decarbonisation in T2. We will continue to monitor technology developments for GIL, and related alternatives to existing cable solutions for underground transmission, and potentially take forward further innovation options in this area when a better overall balance between a cleaner vs efficient outcome can be achieved.

Safety & Environmental

We have invested in innovative Safety & Environmental improvements, which can't be quantified in terms of cost savings but do provide broader benefits (e.g. over 1 million tonnes of carbon saving). 36 NIA projects (totalling £9.0m in investment), with a leverage of £28.5m coming from international utilities through collaborative projects, have provided outputs which contribute to safety and environmental improvements.

TABLE V NIA PORTFOLIO OF PROJECTS FOR SAFETY AND THE ENVIRONMENT (COMPLETED, ONGOING AND IN IDEAS STAGE)

#	Name of Project	NIA Reference	NIA Spend (£k)	Leveraged Project Spend (£k)
Completed Projects				
1	Induced voltages and currents on transmission overhead lines under NSI 4 working practices	NIA_NGET0012	140.8	
2	Tablet interface for a SF6 mass flow top-up device	NIA_NGET0013	44.0	
3	Potentials and profiles around earth electrodes and opposite-side injection for large-area earthing	NIA_NGET0018	229.4	
4	Feasibility Study for Sustainable Substation Design	NIA_NGET0025	87.1	
5	RESNET	NIA_NGET0053	151.7	
6	Electromagnetic transients (EMT) in future power systems – Phenomena, stresses & modelling	NIA_NGET0055	79.9	
7	SF6 Capture & Leakage Repair	NIA_NGET0074	37.0	
8	Temporary Oil Containment	NIA_NGET0075	-	
9	Rapid Deployment Ballistic Screens	NIA_NGET0079	191.8	
10	Cable Oil Regeneration	NIA_NGET0083	1208.5	
11	Impact Assessment of Seismic Analysis on Electricity Towers and Substation Equipment / Structures	NIA_NGET0091	219.4	
12	Incident Investigation Review	NIA_NGET0108	11.1	
13	Enhanced AC and DC safety voltage limits assessment	NIA_NGET0112	312.2	
14	Control of Debris and Dust from the Treatment of Grade 4 Tower Steelwork (G4T)	NIA_NGET0113	210.7	
15	Combustible Gases in Redundant Oil Filled Cables	NIA_NGET0116	47.1	
16	Identification and Mitigation of Large Equipment Transport Issues	NIA_NGET0122	41.9	
17	EPRI Research Collaboration on Electromagnetic Fields and Radio Frequencies	NIA_NGET0124	463.9	5,961.5
18	Determining a threshold for magnetophosphenes perception at 50Hz	NIA_NGET0130	211.2	
19	UltraWire	NIA_NGET0132	118.0	2,750.0
20	Identifying Opportunities and Developments in Electric and Magnetic Fields Research	NIA_NGET0133	141.5	
21	Transient and Clearances in the Future Electrical Transmission Systems (ICASE Award)	NIA_NGET0143	115.6	171.0
22	EPRI Research Collaboration on Electric and Magnetic Fields Health and Safety	NIA_NGET0171	387.4	3,290.0
23	Environmental Containment solutions for Midel 7131	NIA_NGET0178	217.3	
24	EPRI Research Collaboration on Electric & Magnetic Fields Health & Safety (P60) 2016	NIA_NGET0180	416.2	4,076.2
25	Identify opportunities and developments in EMF Research (2016-2018)	NIA_NGET0184	105.0	
26	Portable Earthing Device	NIA_NGET0201	176.4	
27	Novel acoustic attenuation feasibility study	NIA_NGET0203	54.0	
28	Development of Tools for the Assessment and Control of Impressed Voltage	NIA_NGET0207	62.5	
29	Positioning ballistic screening on substation sites	NIA_NGET0212	-	
Ongoing Projects				
30	Stakeholder attitudes to electricity infrastructure	NIA_NGET0107	163.2	
31	SF_6 Management and Alternative Gases	NIA_NGET0163	1,102.3	
32	Investigation of transient and safety issues in gas insulated systems	NIA_NGET0185	162.9	
33	Alternatives to SF6 for retro-filling existing equipment	NIA_NGET0199	320.0	
34	EPRI Research Collaboration on Electric & Magnetic Fields Health & Safety (P60) 2017 -2021	NIA_NGET0208	1,117.6	12,200.0

35	Long Term Stability of Alternative Gases	NIA_NGTO002	341.5
36	High frequency earthing and its impact on the transmission system	NIA_NGTO022	331.5

Project Ideas	
37	**Optimised Infra-red image scans**

High Voltage Direct Current (HVDC) Technologies

We have also 6 completed (totalling £1.3m) and 5 ongoing (totalling £1.4m) NIA projects covering HVDC technology. The portfolio in this area has moved from an understanding of novel HVDC technologies and grids at a time where this technology was expected to flourish, to one of understanding the performance of these through their lifetime and how best to operate and integrate them.

TABLE VI NIA PORTFOLIO OF PROJECTS FOR HIGH VOLTAGE DIRECT CURRENT TECHNOLOGIES (COMPLETED AND ONGOING)

#	Name of Project	NIA Reference	NIA Spend (£k)	Leveraged Project Spend (£k)
Completed Projects				
1	Simulation of multi-terminal VSC HVDC system by means of Real Time Digital Simulation (RTDS)	NIA_NGET0003	84.8	
2	HVDC EngD – Richard Poole	NIA_NGET0042	72.6	
3	Multi-terminal VSC HVDC operation, control and ac system integration	NIA_NGET0045	355.6	
4	DC Circuit Breaker Technologies	NIA_NGET0057	228.3	
5	Application of DC circuit-breakers in DC Grids	NIA_NGET0060	227.7	
6	Controllable Series Impedance at 275 and 400kV (CSI)	NIA_NGET0211	288.3	
Ongoing Projects				
7	VSC-HVDC Model Validation and Improvement (iCASE)	NIA_NGET0166	124.6	230.7
8	The FMEA Studies and Risk-based Maintenance for Emerging Power Electronics Assets within GB Power Networks	NIA_NGTO008	321.1	
9	Voltage source converter based series controlled impedance technology	NIA_NGTO017	669.9	
10	Harmonic Compliance	NIA_NGTO018	109.3	
11	Increasing Transmission Boundary Power Flows using an Active Power Control Unit	NIA_NGTO023	145.8	
Project Ideas				
12	**Risk management for power electronic connections**			

Managing our Network

We have completed 20 projects (totalling £5.8m) investigating technologies and sensors to improve the overall management and operation of our network. We have leveraged £2.8m from collaboration with international utilities and academic institutions. One of these, a £0.4m project, is still ongoing.

Several of these projects started at low technology readiness level and were closed as part of our yearly portfolio management process resulting in low spend.

TABLE VII NIA PORTFOLIO OF PROJECTS FOR MANAGING OUR NETWORK (COMPLETED, ONGOING AND IN IDEAS STAGE)

#	Name of Project	NIA Reference	NIA Spend (£k)	Leveraged Project Spend (£k)
Completed Projects				
1	13kV Shunt Reactor Refurbishment	NIA_NGET0102	1180.8	
2	Bushing and Instrument Transformer Test Tap Connection Condition Assessment Tool	NIA_NGET0109	168.2	
3	Bulk Oil Circuit Breaker Bushing in Situ Refurbishment	NIA_NGET0117	178.1	
4	Understand and Improving Condition, Performance, and Life Expectancy of Substation Assets	NIA_NGET0118	23.8	
5	Condition Monitoring of Circuit Breakers - iCASE	NIA_NGET0186	67.3	169.5
6	Wireless Condition Monitoring Sensors with Integrated Diagnostics	NIA_NGET0033	45.7	
7	Fibre-optic Acoustic Monitoring	NIA_NGET0034	8.7	
8	Enhanced Sensor Development (ICASE Award)	NIA_NGET0135	99.8	294.0
9	Humber Smartzone Pilot Project	NIA_NGET0056	850.0	
10	EPRI Research Collaboration on Grid Planning (P40)	NIA_NGET0191	362.3	2,225.3
11	Study into the Concept of High Impact, Low Probability Events	NIA_NGET0200	93.6	
12	The application of Parametric Design to automate substation development	NIA_NGTO012	67.9	
13	Optimised Location for Surge Arresters on the Transmission Network	NIA_NGET0010	133.8	
14	33kV Superconducting Fault Current Limiter	NIA_NGET0051	10.0	
15	Voltage Optimiser Pilot	NIA_NGET0065	5.0	
16	Network Reliability Asset Replacement Decision Support Tool	NIA_NGET0148	264.0	
17	Life Cycle Costing and Value Optimisation (ICase Award)	NIA_NGET0153	68.3	157.0
18	Feasibility of Risk based Network Planning	NIA_NGET0160	153.9	
19	Feasibility study on the application of advanced materials	NIA_NGET0176	171.2	
20	Detailed design of 400 kV 240MVA Mobile Substation Bay	NIA_NGET0194	1451.8	
Ongoing Projects				
21	Automated identification of failures in HV assets	NIA_NGTO006	444.7	
Project Ideas				
22	**Using artificial intelligence to improve the connection application process**			
23	**System low inertia impact on critical fault clearance time**			
24	**Real time dynamic voltage stability monitoring using PMU data**			
25	**Sub synchronous and near synchronous oscillation in power electronic grid**			

Decarbonisation

Over the last couple of years we have started a new programme of work focussed on decarbonisation. We have completed 2 projects, totalling £0.2m and have 6 ongoing projects totalling £1.5m looking at the decarbonisation of transport, heat, and technologies to utilise the operation of our network to enable faster deployment of renewable generation. At present, the carbon intensity of the electrical system varies a lot depending on the time of day and season. This fluctuation can be a barrier for low-carbon technologies which would benefit from increased flexibility and services in the network.

The programme has a leverage of £2.8m coming from international utilities through collaborative projects, which have provided insights and learning from how utilities worldwide have managed the integration of charging stations and vehicle-2-grid/grid-2-vehicle technologies at transmission level.

TABLE VIII NIA PORTFOLIO OF PROJECTS FOR DECARBONISATION (COMPLETED, ONGOING AND IN IDEAS STAGE)

#	Name of Project	NIA Reference	NIA Spend (£k)	Leveraged Project Spend (£k)
Completed Projects				
1	Decarbonisation vision for South Wales	NIA_NGTO021	135.6	
2	EPRI Research Collaboration on Electric Transportation (P18)	NIA_NGTO007	62.4	2,755.9
Ongoing Projects				
3	Electric Road System for Dynamic Charging of Electric Vehicles	NIA_NGTO001	260.5	
4	Feasibility study in to unlocking flexibility within UK Steel Works	NIA_NGTO0031	160.6	
5	Energy Highways	NIA_NGTO011	321.0	
6	WATTS – Weather Analytics for The Transmission System	NIA_NGTO016	341.6	
7	Unlocking Transmission Transfer Capacity	NIA_NGTO019	139.6	
8	Overload Rotation to Increase Capacity of Transmission Boundaries	NIA_NGTO030	97.6	
Project Ideas				
9	Electrification of long unelectrified routes			
10	Achieving Net Zero for South Wales			
11	Feasibility study into the use of automated electrified ships and HGVs for the national transport of hydrogen			
12	Maximising transmission capacity for offshore renewable deployments through electrolysis			
13	Impacts of hybrid low carbon heat energy solutions on electricity transmission network			
14	Development of modular, mobile transmission technologies for fast connection of renewables and new loads			

Other

We have two projects where we have had NIA spend which are registered by another utility as well as a £400k spend attributable to NIC bid preparation costs. These are represented in the table below. This expenditure equates to £0.6m of NIA costs.

#	Name of Project	NIA Reference	NIA Spend (£k)	Leveraged Project Spend (£k)
Completed Projects				
1	Resource and asset reuse toolkit	NIA_NGGT0047	61.3	
2	HVDC Nanocomposite Insulation	NIA_SHET0008	123.4	
3	Bid Preparation costs		379.8	

Deeside Centre for innovation (Network Innovation Competition)

To support our transformative innovation, we were successful in winning a Network Innovation Competition, resulting in an investment of £24m (£14m of which is funded by National Grid) to convert a decommissioned substation into an offline test and evaluation facility, which is the first of its kind in Europe. This facility, known as the Deeside Centre for Innovation, will allow us and other organisations to trial technologies and new practices without putting the network and service to consumers at risk. In T1 the 5 innovation projects detailed are estimated to deliver over £24m of avoided costs (not directly contributing to consumer savings).

We have these 5 active projects and over 100 proposals under consideration. These projects have been developed and approved through our governance process and in conjunction with the other network licensees, both at transmission and distribution level. Whilst they might have a minimal impact on our T1 performance due to the fact they will not be complete until 2020, the implementation of these innovation outputs across the whole of the UK can deliver the benefits outlined below:

1. **Retrofit Cable Sealing Ends:** Retrofit cable sealing ends offer the opportunity to reduce the amount of work required during the replacement of a cable sealing end; removing the need for an additional joint and the associated ground works. This should reduce the cost of replacements significantly and allow them to be delivered faster
2. **Textured Insulators:** Textured composite insulators are a novel design that dramatically improves composite insulator performance. We are working with Cardiff University and Allied Insulators to develop, optimise, and deliver the world's first Textured insulator. Textured insulators offer the opportunity to unlock cost savings during overhead line replacement and when building new routes. They may also allow us to improve the way we manage insulators; as they allow defects to be identified more easily and provide more time to plan repairs.
3. **Non-invasive Tower Foundation Inspections:** This project is seeking to test multiple methods of assessing the condition of overhead line tower foundations, without the need for costly excavations. This project will leverage the existing experience and data available to NGET and perform tests to understand how reliable non-invasive tower foundation technologies are. These data sets will be combined to allow a risk tool to be developed, which will lead to a reduction in the number of tower foundation excavations.

4. **Rapidly Deployable Scaffold:** When replacing cable sealing ends, the scaffold required to provide access and a safe working environment makes up a significant proportion of the overall cost. Current practice and technology also adds significant time to the replacements. This project will develop a rapidly deployable solution, which can save time and reduce repeated design costs.
5. **Modular Bunds:** Modular bunds offer the opportunity to reduce the installation times and costs when building new bunds for transformers and other large, oil-filled assets. The modular bund uses prefabricated concrete blocks to save time during installation and can reduce the overall impact of delays on larger infrastructure projects or customer connections by utilising the benefits of off-site construction.

The next phase of projects at Deeside which we are aiming to start in early 2020 is going to focus on using the newly available overhead line facilities; while construction continues on the main substation area. Other substation projects will be run in parallel with the construction of the main substation area, but the focus will be on overhead line technology.

Below is a short summary of the projects we have in development:

Project Proposals	Project Description	Status
Conductor Coatings	Preventing ice build-up on overhead line conductors, can allow us to push the assets harder and use the available capacity of our existing infrastructure more effectively. By strategically placing the coatings, we can improve power flows in a much shorter period of time, with minimal upgrading of the conductors.	Initial Proposal Developed
Vibration testing of HTLS conductors	There is limited data on wind-induced vibration on new High Tension Low Sag (HTLS) conductor - testing of this conductor could enable better understanding of this conductor performance and self-damping capabilities. If we understand these properties in more detail, we can increase power flows by tensioning the conductors more (reducing the overall sag on a given route).	Assessment Stage
Conductor and fittings fatigue life	Understanding the fatigue life of conductors would enable better prediction of conductor asset life and allow us to life extend in many cases. This can reduce Opex costs and allow us to defer maintenance.	Assessment Stage
Low stress spacers	Novel spacers could be designed with the experience of where the damage on the conductor is most often found. These novel spacers could reduce/remove one of the life limiting effects on conductors and ensure that when we invest in the network, we get the most out of that investment.	Idea
Corona on OHL Fittings	Testing the corona performance of overhead line fittings could allow us to change/relax our technical specifications in this area.	Idea
OHL sensors	Investigating conductor condition monitoring using ultrasonic and guided wave technology, could allow us to understand the condition of overhead line conductors. This could provide a step change in how we determine the condition of overhead line conductors.	Idea
Video Recognition of Asset Condition	Overhead line conductors and fittings are inspected using video footage from helicopters. Assets can be aged at Deeside, installed on the overhead line and then videoed. These videos can then be processed to automatically identify faults on equipment, rather than relying on human analysis.	Assessment Stage

Collaboration

Throughout T1 we have co-funded 8 projects with the other TO and DNO licensees through NIA funds, and actively supported with the implementation and roll-out of 27 others across the UK. As part of our Deeside Programme, we have a Technology Advisory Board consisting of all willing DNOs and TOs in the UK and academic partners. Through collaboration with EPRI utilities, we have leveraged a total of £115m from over 100 international electricity utilities through 21 projects. Through the EPSRC, we have leveraged over £120m through collaboration with academic institutions in the UK and over 300 UK and international organisations. We have also supported our suppliers and other UK infrastructure companies such as Highways England in ideation workshops as part of an Open Innovation programme.

Learning through Stakeholder Engagement in T1

Based on feedback from our stakeholders and in response to the Paris Climate Agreement and also the vote to leave Europe, during T1 we modified our approach to innovation and our plan around our innovation spend to meet these needs. Below are the largest changes we made:

Stakeholders said	We Did
The innovation process is too long and labour intensive; there are too many steps; it takes over 5 months to get a project approved.	In 2016, we reviewed the innovation process and the structure of the innovation team. Through lean design we restructured the team and reduced the time to get a project through governance to 1 month by January 2017.
The time it takes to implement and roll-out a technology in the industry has a negative impact on the investment case into R&D in the energy sector and the creation of spin-outs and growth of SMEs.	We sought funding for the development of the Deeside Innovation Centre from Ofgem with 50% leverage from our shareholders (£14m).1 The aim is to develop an environment capable of reducing the time between proof-of-concept to roll-out of new technologies to 2-3 years, in line with the electronics and automobile sector.
Organisations who innovate as part of their business have high overheads and therefore tend to fail at the time of winning tenders. Furthermore, new technologies are initially more expensive and fail to win when the weighting given in the procurement process to the upfront cost is so high.	We worked with procurement to look at how we could support the introduction of new technologies whilst at the same time delivering best value to our consumers in the short-term. We have reviewed the tender process to include innovation in the weighting of the responses where appropriate. We also looked at the mechanisms available to contract for innovation work. In this process we discovered the “Innovation Partnership” contractual mechanism and put our first contract in place for Gas Insulated Lines.
Government and regulators need to develop an infrastructure programme and market that will enable the	We modified our innovation strategy and re-directed 15% of our budget to develop a programme in electrification of

fulfilment of our Paris commitments and there is significant uncertainty and no clear path.	transport and roads, as well as the future energy networks. We committed 3 full-time innovation engineers to this endeavour. We increased our attendance and involvement in conferences to understand and engage with the wider market segments. We became members of Flexis, the Cheshire Energy Hub and lead the South Wales Cluster study.
The cost of electricity in the UK is higher than in other European nations such as Germany, potentially driving heavy industry out of the UK.	We committed one full-time innovation engineer and 5% of our budget to develop a co-creation programme with industry to electrify their carbon intensive processes and, where appropriate, develop a plan for them to reduce their carbon footprint.
Small and medium enterprises working in the energy sector want support to grow their business and understand how to engage with the energy sector.	We developed and reached out to SMEs through Innovation Competitions (such as the Master of Innovation where we funded 12 proof of concept projects), the Low Carbon Network Innovation Conference and social media. We increased our presence as speakers in UK energy related conferences. We engaged with two incubators, RocketSpace and The Enterprise Hub, managed by the Royal Academy for Engineering.
Academic institutions and government funding bodies expect a reduction in budget for R&D activity and want to maximise the impact they can deliver by improved alignment and collaboration.	We increased our direct engagement with government funding bodies becoming board members of the Strategic Advisory Board for UKRI and Industrial Board for the Supergen Energy Hub. We increased our engagement with organisations such as the IET and the Royal Academy of Engineering.
Academic institutions are concerned their capability to apply for European funding will suffer and this in turn will have an impact on their international standing and capability to recruit good talent into engineering disciplines and maintain their international reputation.	We submitted a proposal to the EPSRC for a 5-year programme of work leveraging our funding, front loaded in T1 with National Grid funding to reduce funding uncertainty and fill the gap across regulatory periods.