MANAGEMENT OF ENERGY NETWORKS

PERSPECTIVES ON ADOPTING MATHEMATICAL TECHNIQUES IN TO ENERGY UTILITIES

RAMBOLL

DISCUSSION

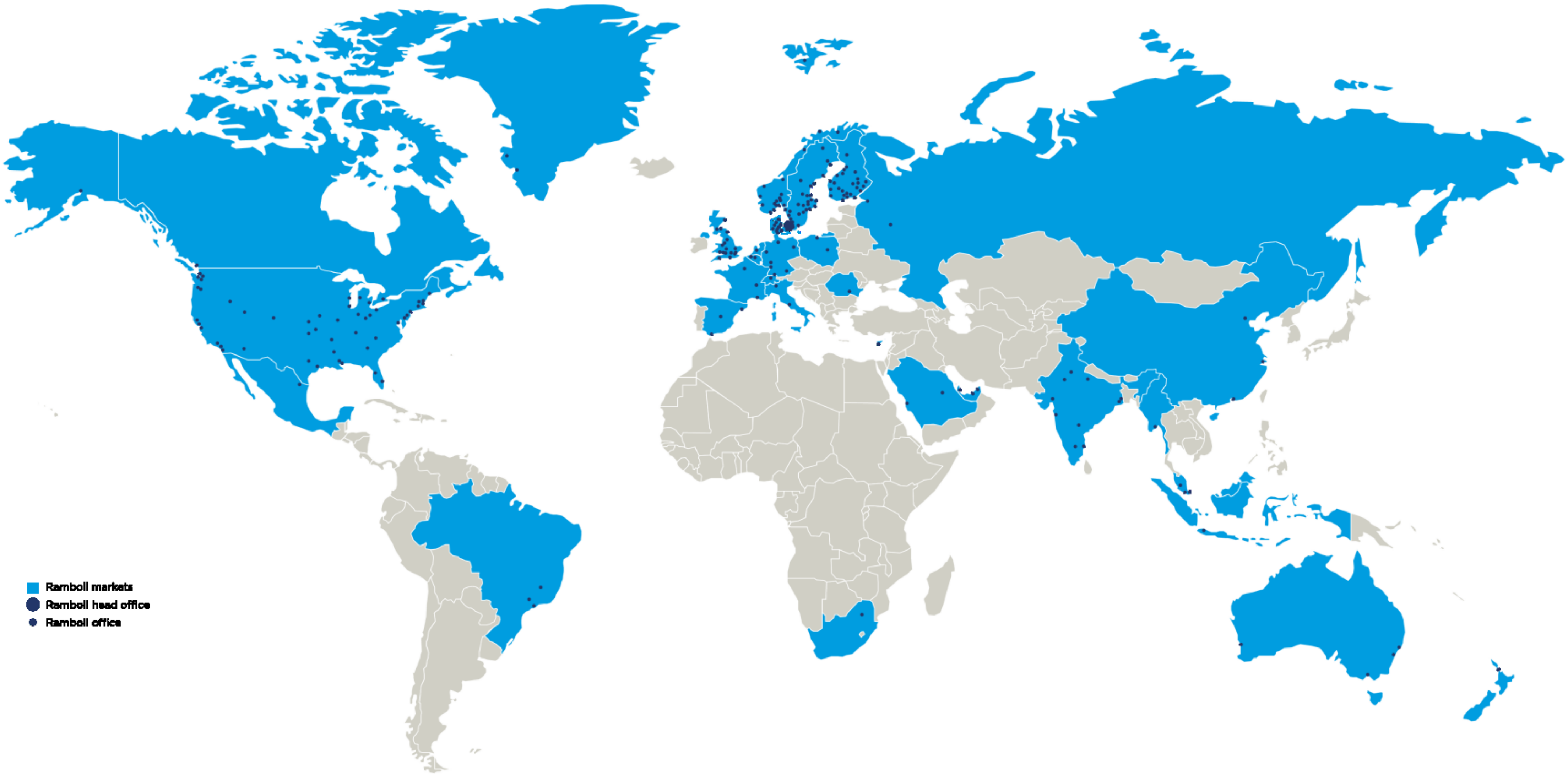
- Who are Ramboll
- Who am I?
- Techniques used in utilities
- Regulated entities and the regulator
- Innovation
- Summary

RAMBOLL IN BRIEF

- Independent engineering and design consultancy and provider of management consultancy
- Founded 1945 in Denmark
- 13,000 experts
- Close to 300 offices in 35 countries
- Particularly strong presence in the Nordics, the UK, North America, Continental Europe, Middle East and Asia Pacific
- EUR 1.4 billion revenue
- Owned by Ramboll Foundation

- Services across the markets:
  - Buildings
  - Transport
  - Planning & Urban Design
  - Water
  - Environment & Health
  - Energy
  - Oil & Gas
  - Management Consulting

GEOGRAPHICAL FOOTPRINT



MARKETS

Buildings	Transport	Planning & Urban Design	Water	Env. & Health	Energy	Oil & Gas	Mgmt. Consulting
Revenue: 409 m€ Employees: 3,700	Revenue: 323 m€ Employees: 2,900	Established 1. May 2015 Approximate employees: 500	Revenue: 80 m€ Employees: 741	Revenue: 154 m€ Employees: 2,300	Revenue: 117 m€ Employees: 700	Revenue: 84 m€ Employees: 800	Revenue: 76 m€ Employees: 600








RAMBØLL

REVIEW OF THE TRANSMISSION AND GENERATION PLANNING CRITERIA, KINGDOM OF SAUDI ARABIA

Challenge

Review the principals of transmission and generation planning

What we do

Review current approach against international best practice and develop coherent policies for future planning

Effect

Flagship waste-to-energy facility from an environmental and energy efficiency point of view

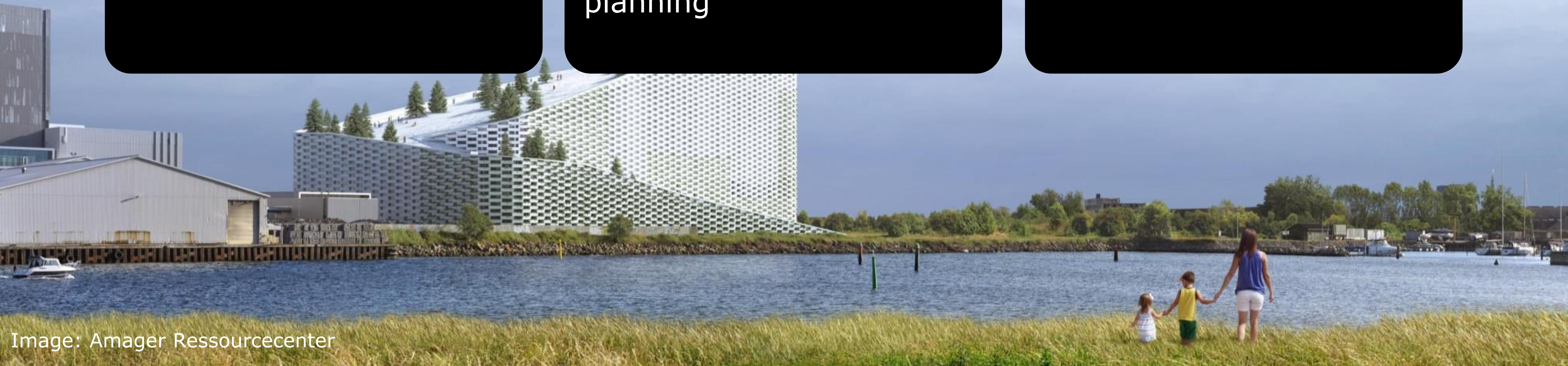


Image: Amager Ressourcecenter

KPI IMPLEMENTATION AND AUDIT, KINGDOM OF SAUDI ARABIA

Challenge

Implement performance metrics on the electricity utilities (generation, transmission, distribution, supply) for regulatory monitoring

What we did

Revision of the KPI metrics and annual audits of the submitted data

Effect

Consistent, transparent approach to generation and transmission planning

RAMBOLL

WHO AM I

THE UNIVERSITY OF EDINBURGH

1994

AEP AMERICAN ELECTRIC POWER

2004

NORTHERN POWERGRID

2012

1998

National Grid

2006

PB PARSONS BRINCKERHOFF 100 YEARS

2016

RAMBOLL

RECENT PROJECTS

هيئة تنظيم الكهرباء والإنتاج المزدوج

ELECTRICITY & CO-GENERATION REGULATORY AUTHORITY

TRANSMISSION LICENCE

No (020307 – R)

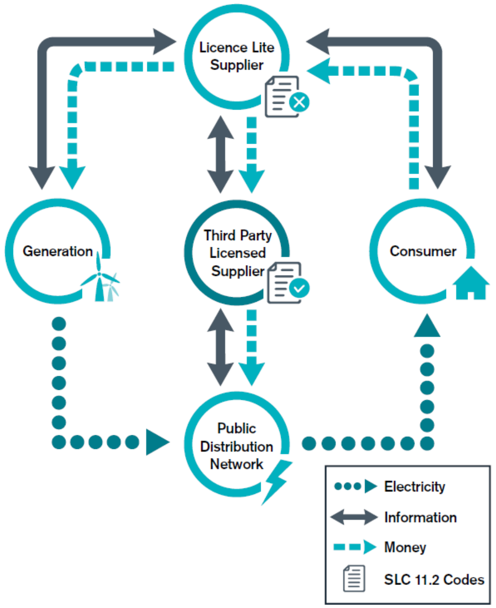
GRANTED BY

THE ELECTRICITY AND CO-GENERATION REGULATORY AUTHORITY

FOR

NATIONAL ELECTRICITY TRANSMISSION COMPANY

Version No.	(2)	Date	23/05/1433 – 15/04/2012



Year	ENS
2011	0.0035
2012	0.0041
2013	0.0047
2014	0.0031
2015	0.0063

$$MAIFI = \frac{\Sigma_i(M_i)}{N_T}$$

$$SAIDI = \frac{\Sigma_i(N_i \times d_i)}{N_T}$$

$$Losses\ (\%) = \frac{E_{n_{in}} - E_{n_{out}}}{E_{n_{in}}} \times 100$$

KPI	Published 2016 KPI	
T1: ENS	0.0036	%
T2: SAIDI-T	61.407	Minutes per customer
T3: SAIFI-T	0.349	Interruptions per customer
T4: MAIFI-T	0.069	Interruptions per customer
T5: Outages per 100km	3.481	Outages per 100km
T6: Voltage Dips	36	number
T7: Network Losses		Not Reported

Source: National Grid KPIs for 2016-12 Months (ECRA Template).xlsm

Transmission KPIs		Target Set	Monitoring Purpose	Supporting Information
T1	Energy Not Supplied	X		
T2	System Average Interruption Duration Index		X	
T3	System Average Interruption Frequency Index		X	
T4	Momentary Average Interruption Frequency Index		X	
T5	System Availability	Planned	X	
	Line Availability			X
	Transformer Availability			X
T6	Voltage Dips		X	
T7	Network losses	Starting 2017		
Transmission Efficiency				X

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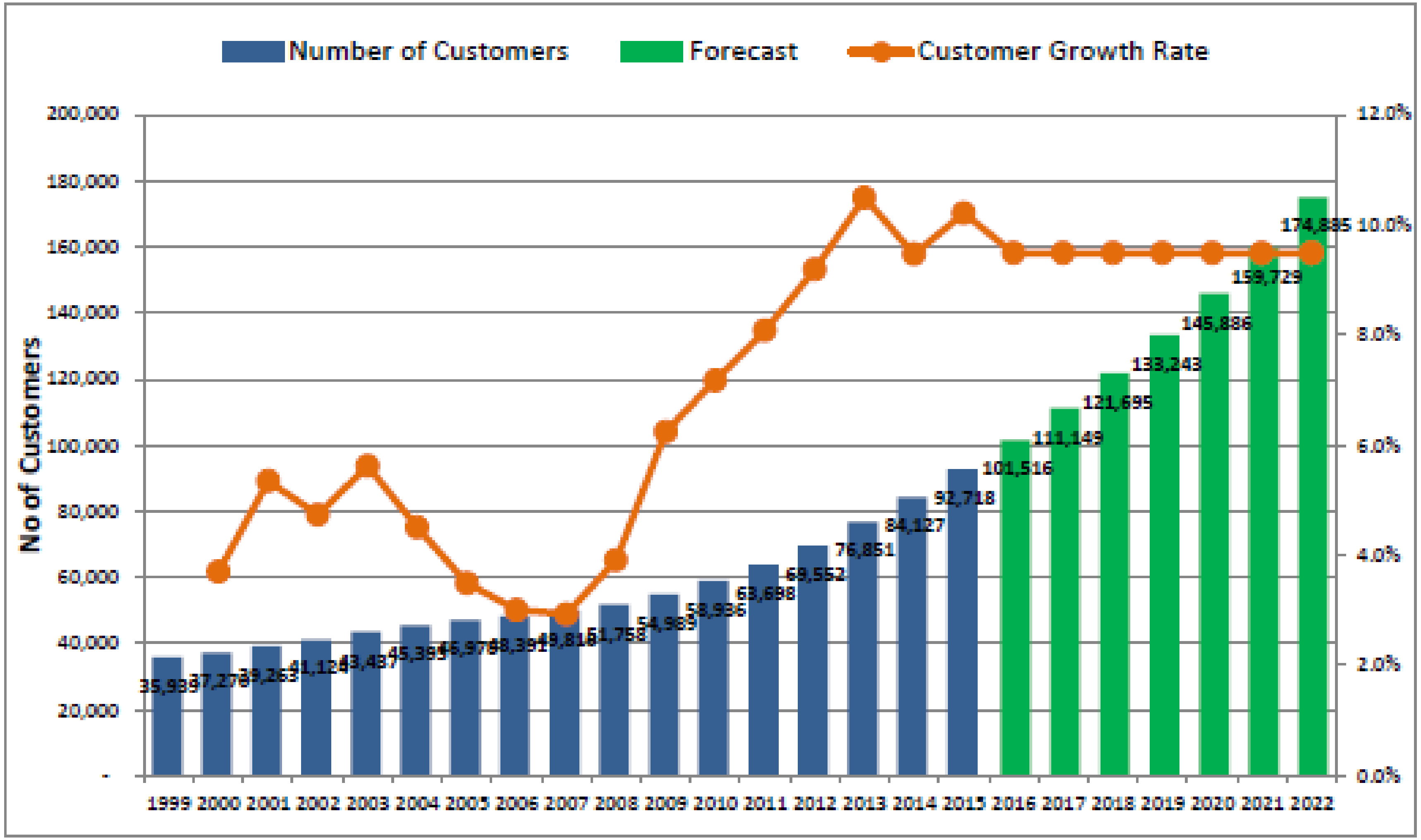
TECHNIQUES USED IN UTILITIES

DRIVER: CUSTOMER GROWTH - OMAN

- Figure 4-1: Historic and Forecast Growth in Customers Connected to the DPC System



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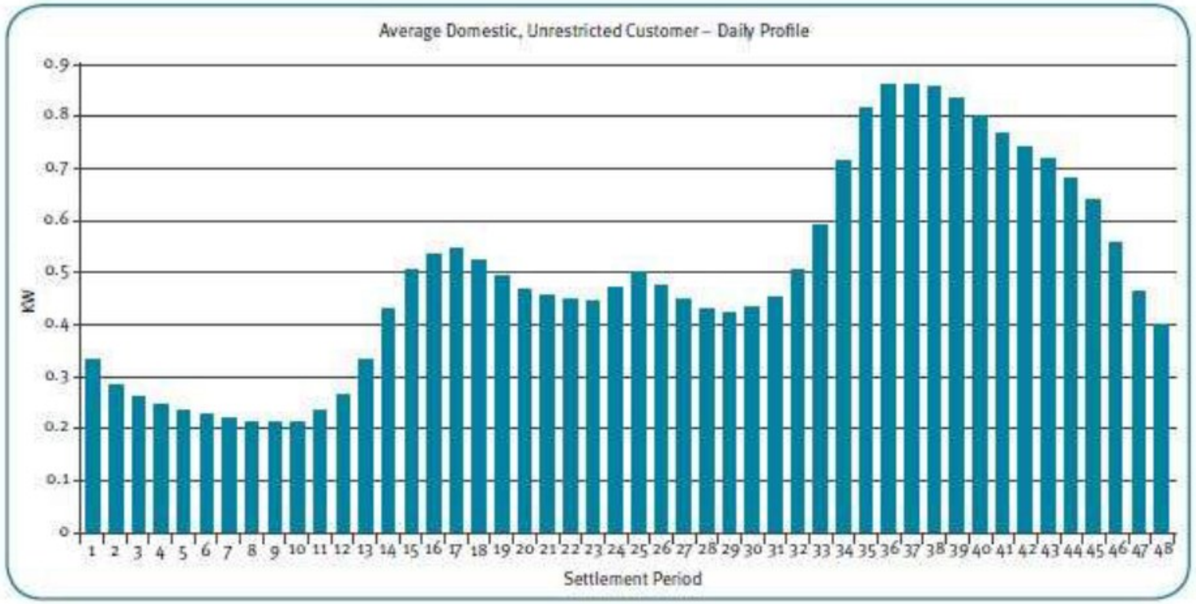
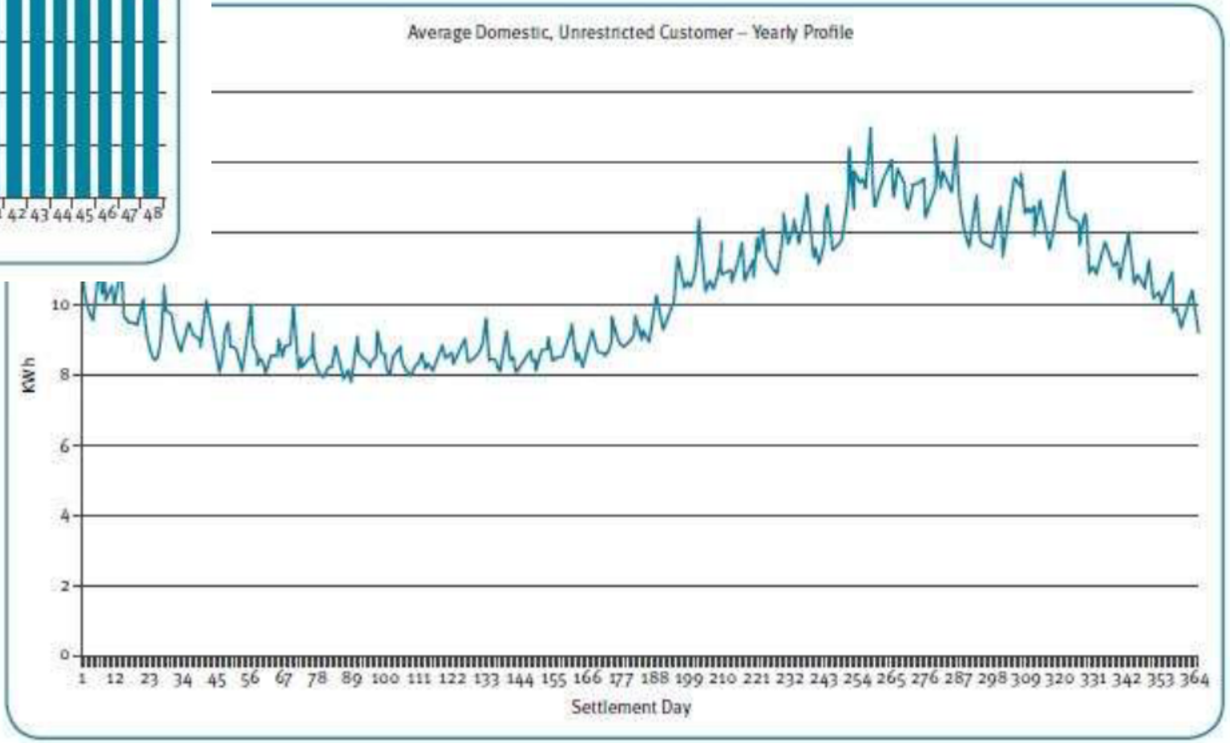
DRIVER: AVERAGE CUSTOMER PROFILES - UK





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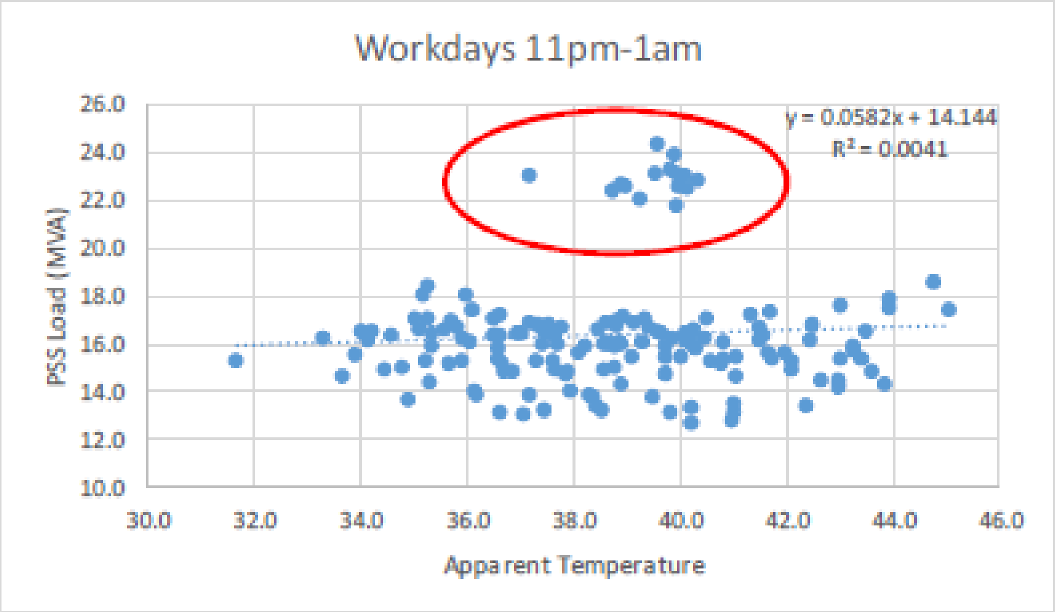
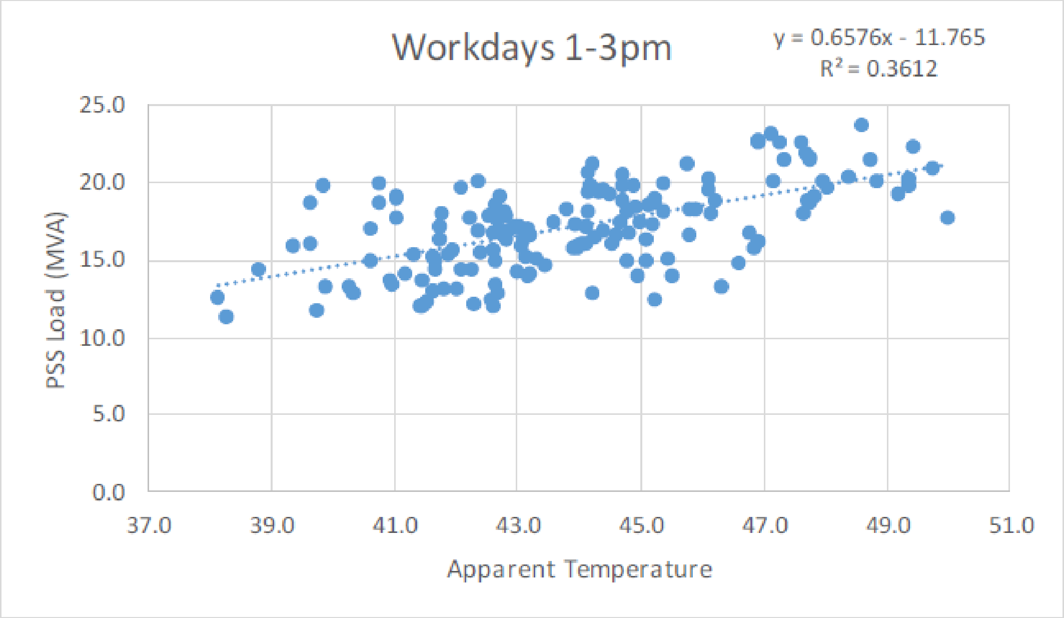
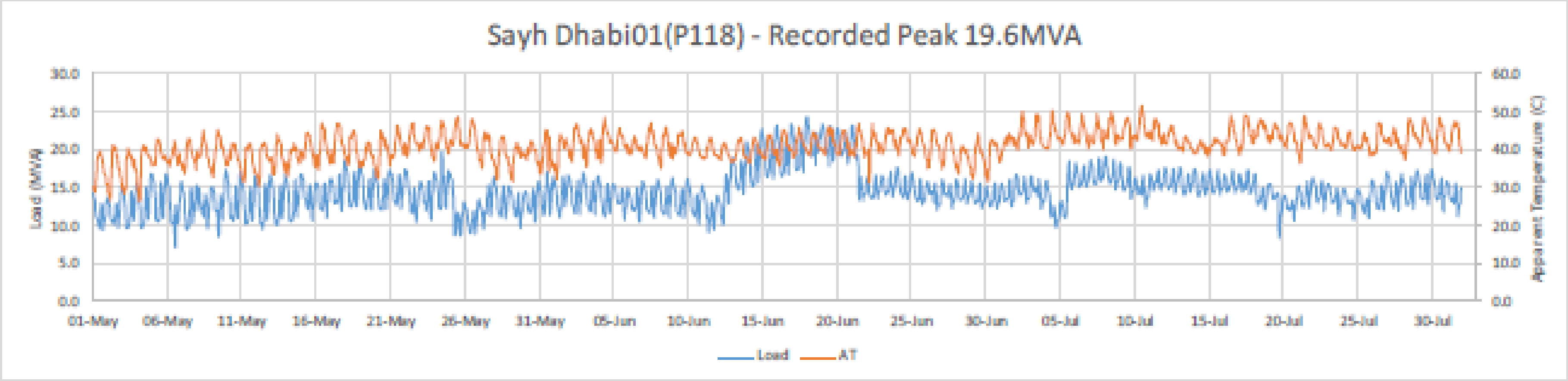
DRIVER: TEMPERATURE CORRECTION - OMAN







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DRIVER: ELECTRICITY SECURITY OF SUPPLY

Less Probable Contingencies

Less probable contingencies involve busbar faults leading to the loss of two or more elements. The acceptable system impact is as follows:

1. Loss of load allowed
2. The system should be transiently and dynamically stable.
3. No voltage collapse, cascading or overloads exceeding the emergency rating of the transmission equipment.

For a Less Probable Contingency the loss of two or more elements causing loss of load shall be controlled / planned and documented.

Non – Simultaneous Contingencies

This is often referred to as (N-1-1) event. It includes an outage condition involving single contingency followed by system adjustments and another single contingency. The acceptable system impact under (N-1-1) is as follows:

1. The system should perform within emergency limits following either outage and within normal limits after system adjustments. System adjustments include tap changing , switching of shunts and generation re-dispatch.
2. Loss of load allowed.
3. To cater for extended outage of one of two cables supplying a discrete group, the system should be tested to have enough transfer links to meet 2/3 of the group peak demand.
4. The system should be transiently and dynamically stable.

DRIVER: ASSET REPLACEMENT - UK

Figure 3.11
High-level network option considerations

Utilise existing assets

Upgrade existing assets
E.g. increase the thermal capability of an existing overhead line

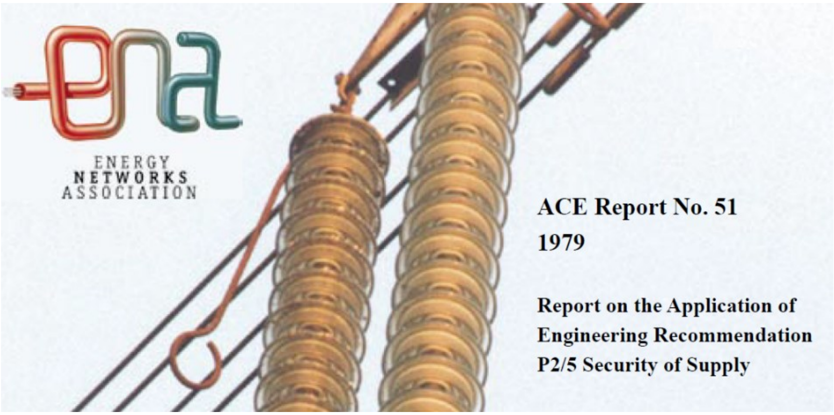
Replace existing assets
E.g. reconductor an existing overhead line

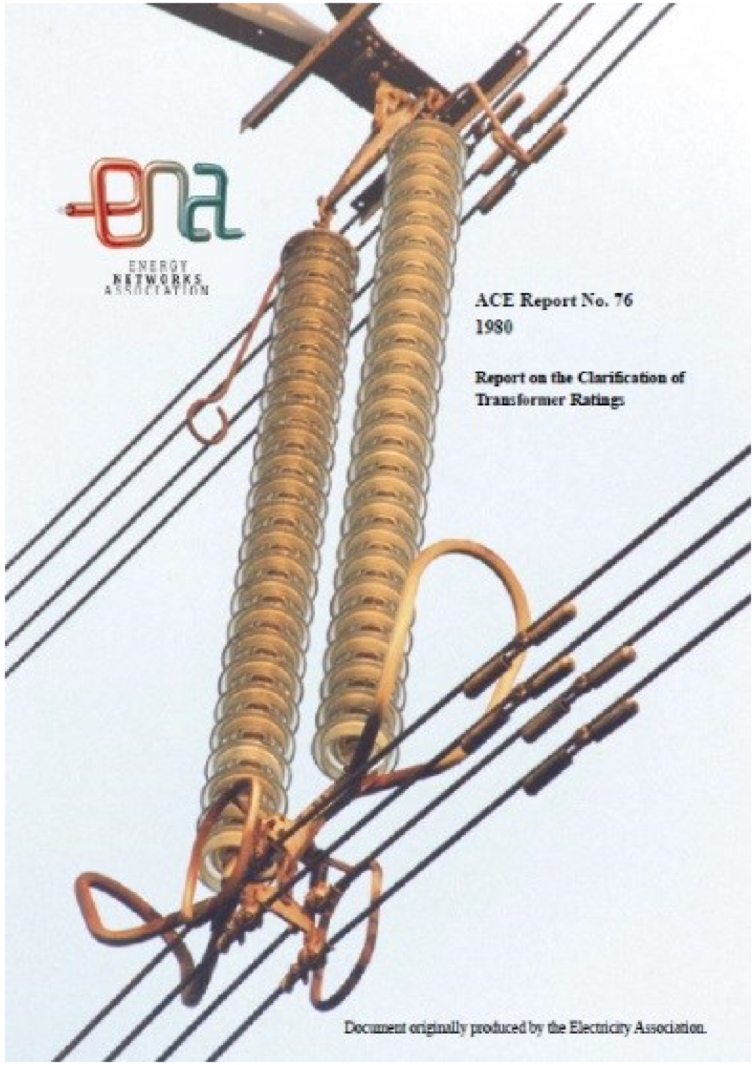
Construct new assets
E.g. construct a new transmission circuit

DRIVER: ASSET MANAGEMENT – PREDICTING FAILURES

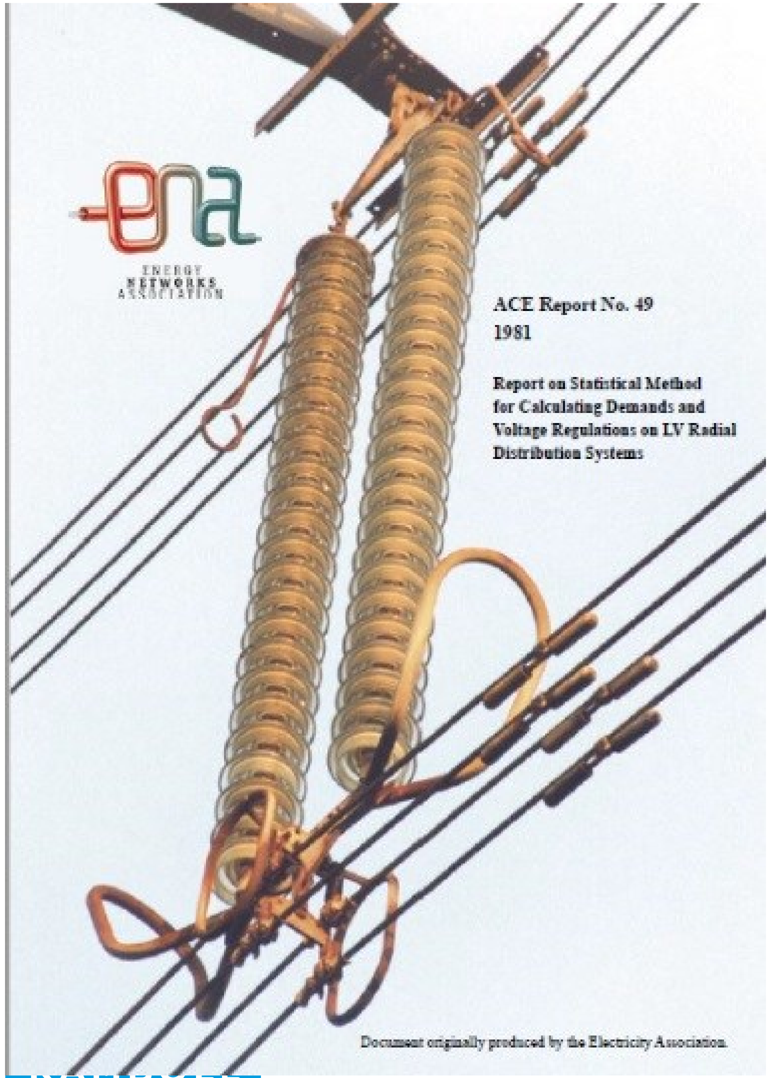
TABLE B.1

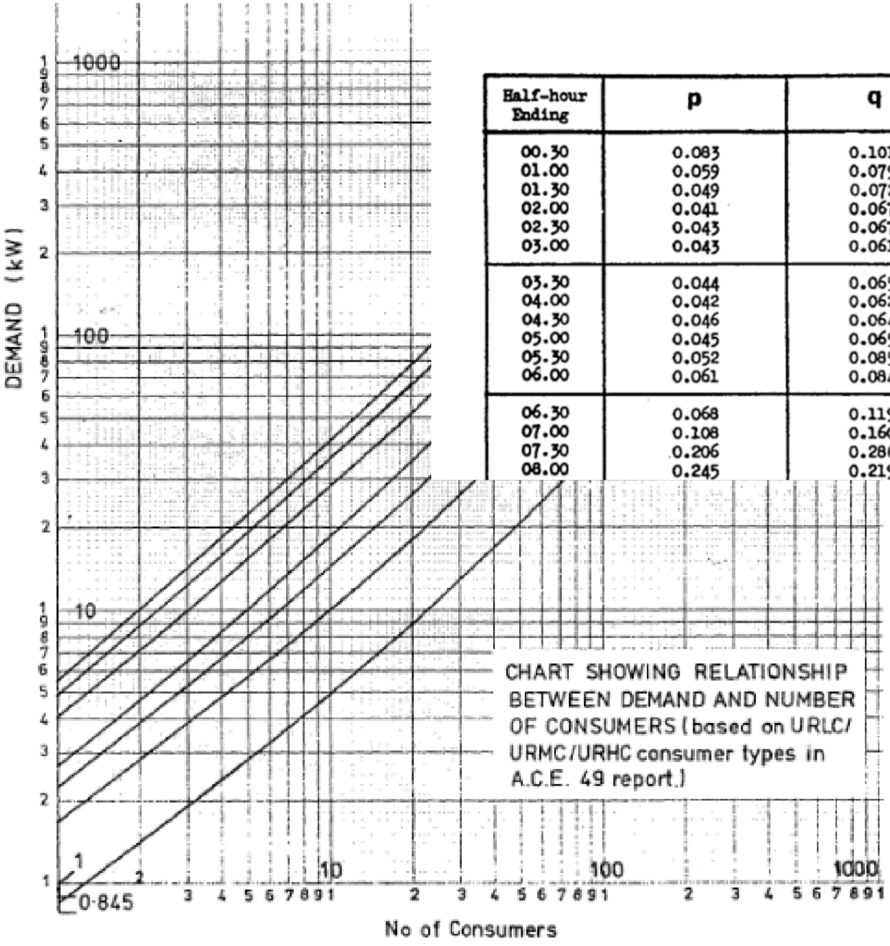
	Fault Rate Number per Year	Average Outage Duration	
		Hours	Years
33 kV Busbar	0.001	2	0.00023
33 kV Circuit Breaker	0.003	76	0.0087
33 kV Cable—4 km	0.1	200	0.0228
33/11 kV Transformer	0.015	350	0.0400
11 kV Circuit Breaker	0.003	24	0.0027
11 kV Busbar	0.001	2	0.00023





PROCESS: CALCULATING DEMAND





UNRESTRICTED CONSUMER GROUPS

Electric cooker	Yes
Electric water heating	Yes
Main living room electric space heating	Yes

Half-hour Ending	p	q	P	Q
00.30	0.083	0.101	0.56	0 68
01.00	0.059	0.079	0.40	0.53
01.30	0.049	0.072	0.33	0.49
02.00	0.041	0.067	0.28	0.45
02.30	0.043	0.067	0.29	0.45
03.00	0.043	0.061	0.29	0.41
03.30	0.044	0.065	0.30	0.44
04.00	0.042	0.062	0.28	0.42
04.30	0.046	0.064	0.31	0.43
05.00	0.045	0.065	0.30	0.44
05.30	0.052	0.085	0.35	0.57
06.00	0.061	0.084	0.41	0.57
06.30	0.068	0.119	0.46	0.80
07.00	0.108	0.160	0.73	1.08
07.30	0.206	0.286	1.39	1.93
08.00	0.245	0.219	1.66	1.48

PROCESS: GENERATION PLANNING (LEAST COST)

Plant Type	Deterioration margin (% / per annum)
Thermal boiler (steam)[5]	1.5
Open cycle gas turbine[6]	2
Combined cycle gas turbine[7]	2
Diesel	0
Wind turbine[8]	1
Solar PV array[9]	0.5
Waste to Energy	1.5

$$Expected\ Unserved\ Energy = \left(1 - \left(\frac{(Total\ Energy - Unserved\ Energy)}{Total\ Energy}\right)\right) \times 100$$

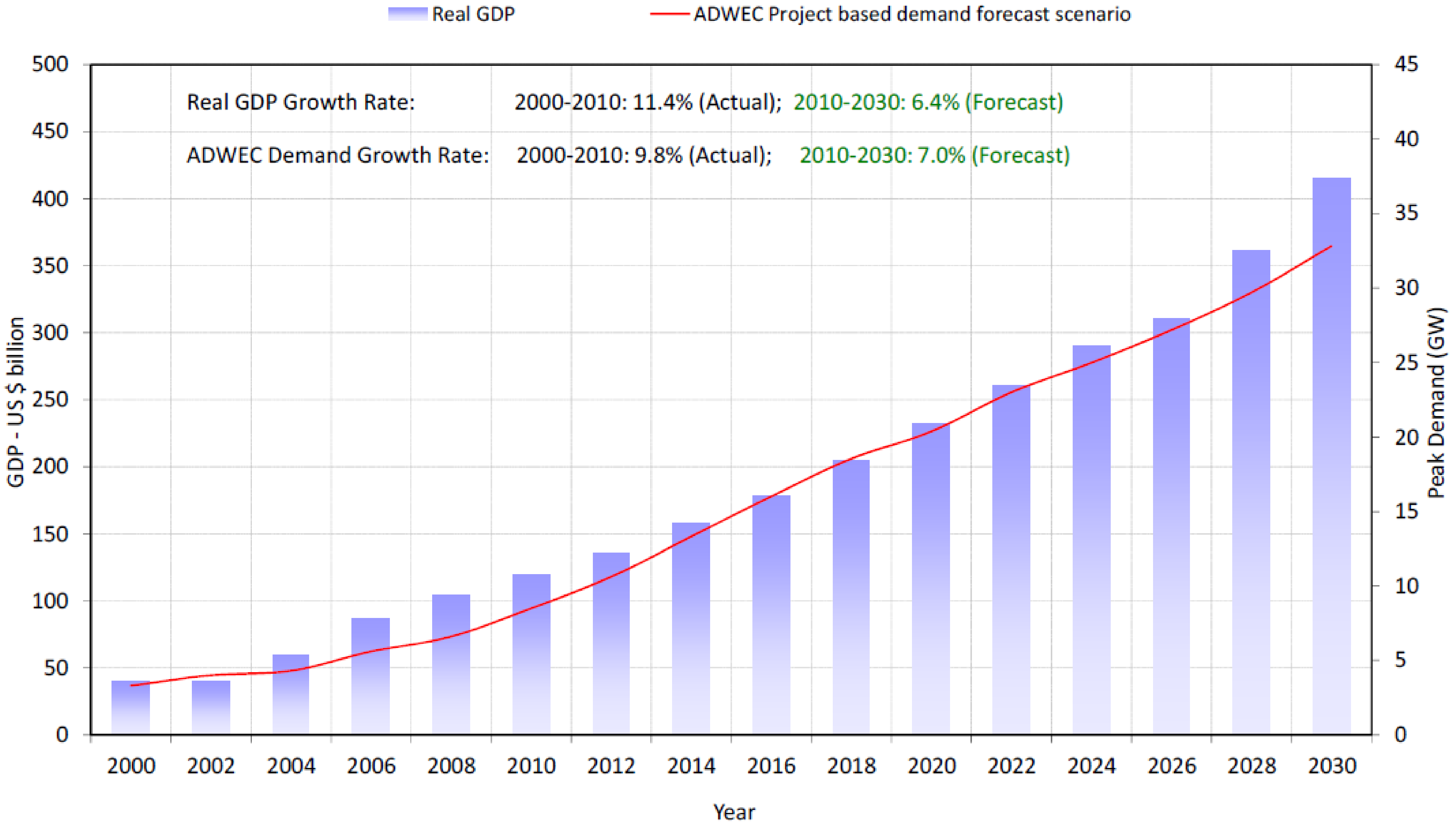
$$Expected\ Unserved\ Energy = \left(1 - \left(\frac{(1{,}200 - 25)}{1{,}200}\right)\right) \times 100$$

$$Expected\ Unserved\ Energy = 2.0\%$$

Loss of load Expectation

A Loss of Load Expectation (LoLE) value is a measure of scarcity in available surplus generation capacity and is measured in the number of hours that load is interrupted during the period. That is, for a given level of generation at system peak demand the associated LoLE indicates the probability that there will be insufficient generation capacity to meet the system demand.

OUTPUT: DEMAND GROWTH – ABU DHABI



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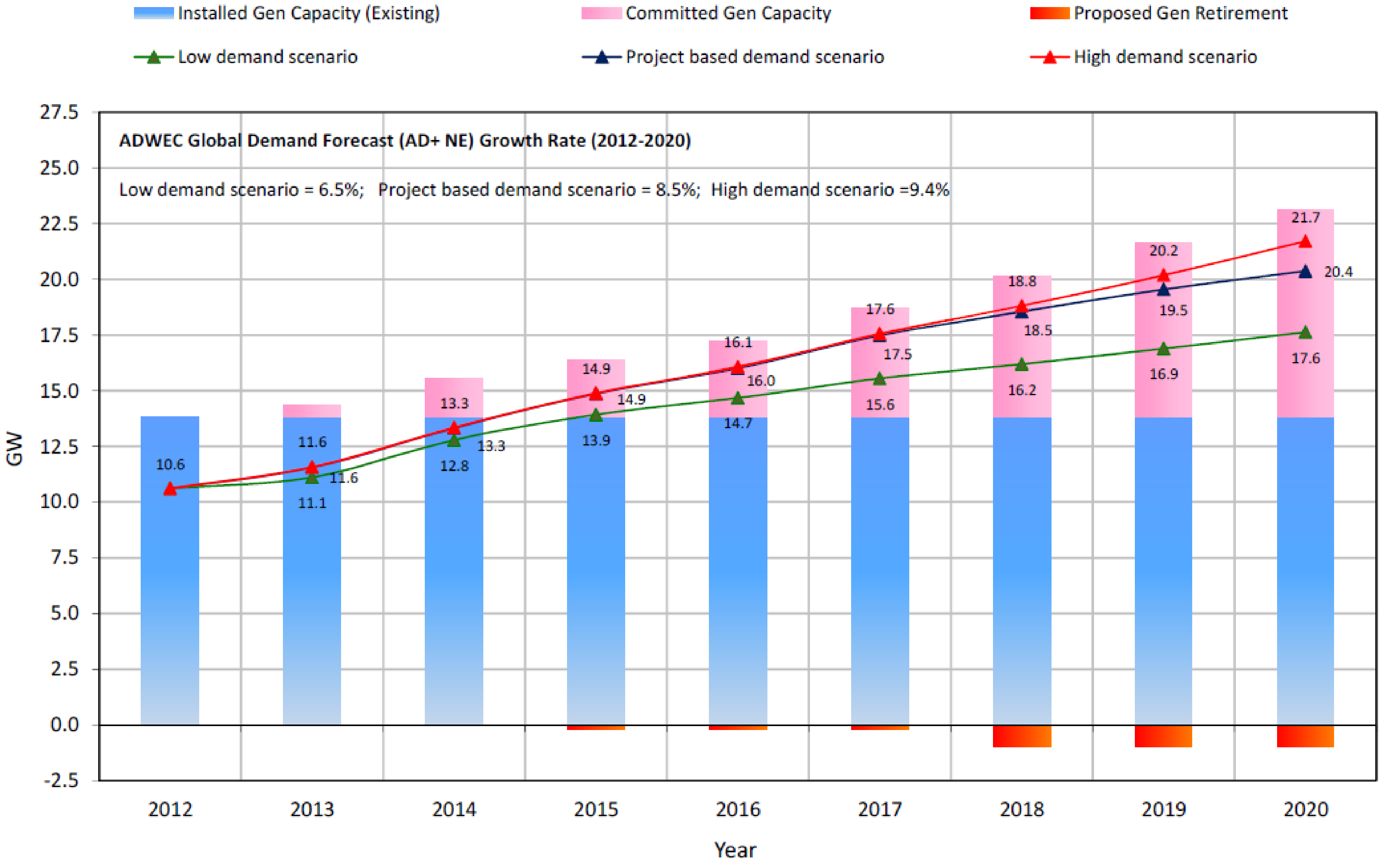
OUTPUT: GENERATION CONSTRUCTION – ABU DHABI



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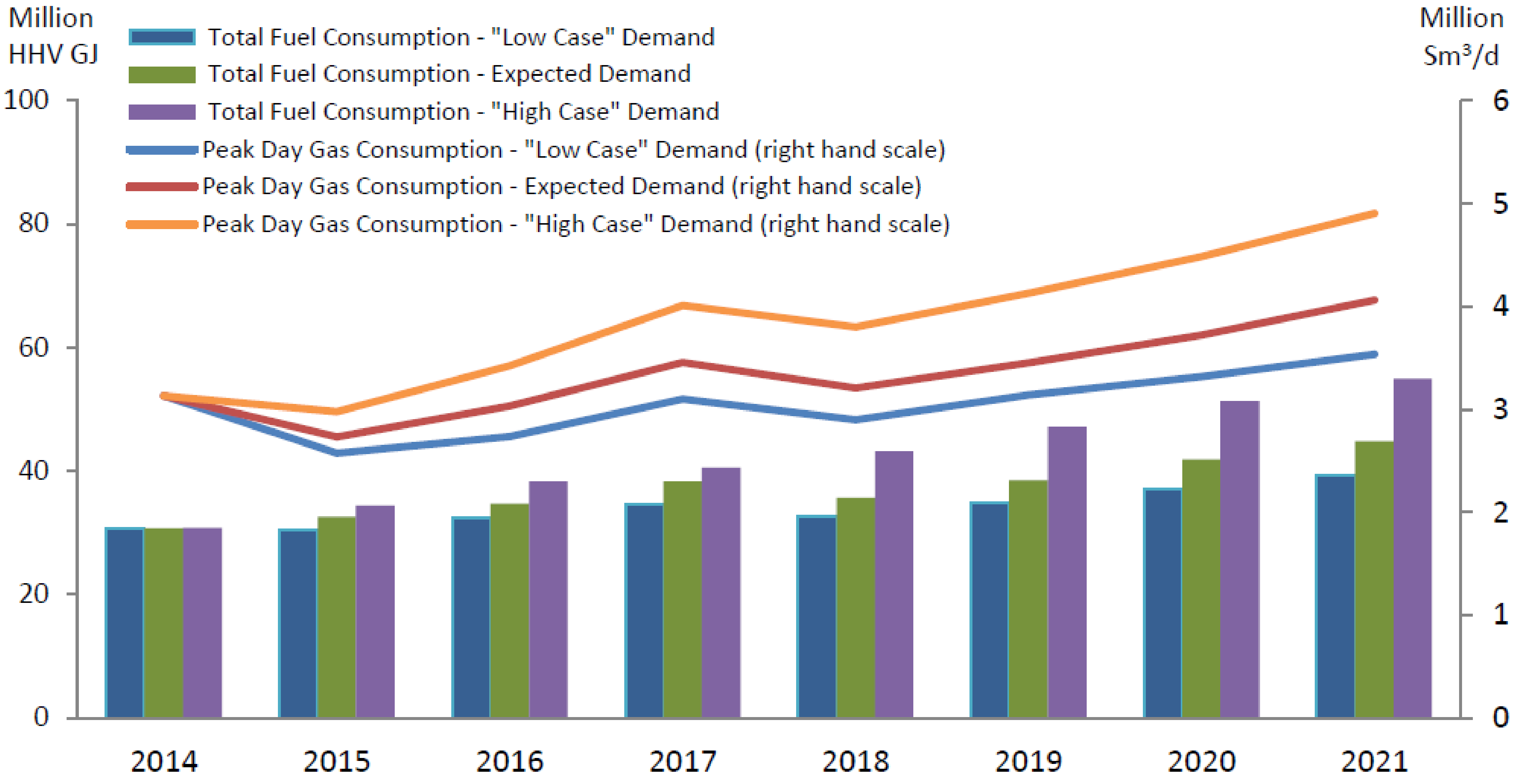
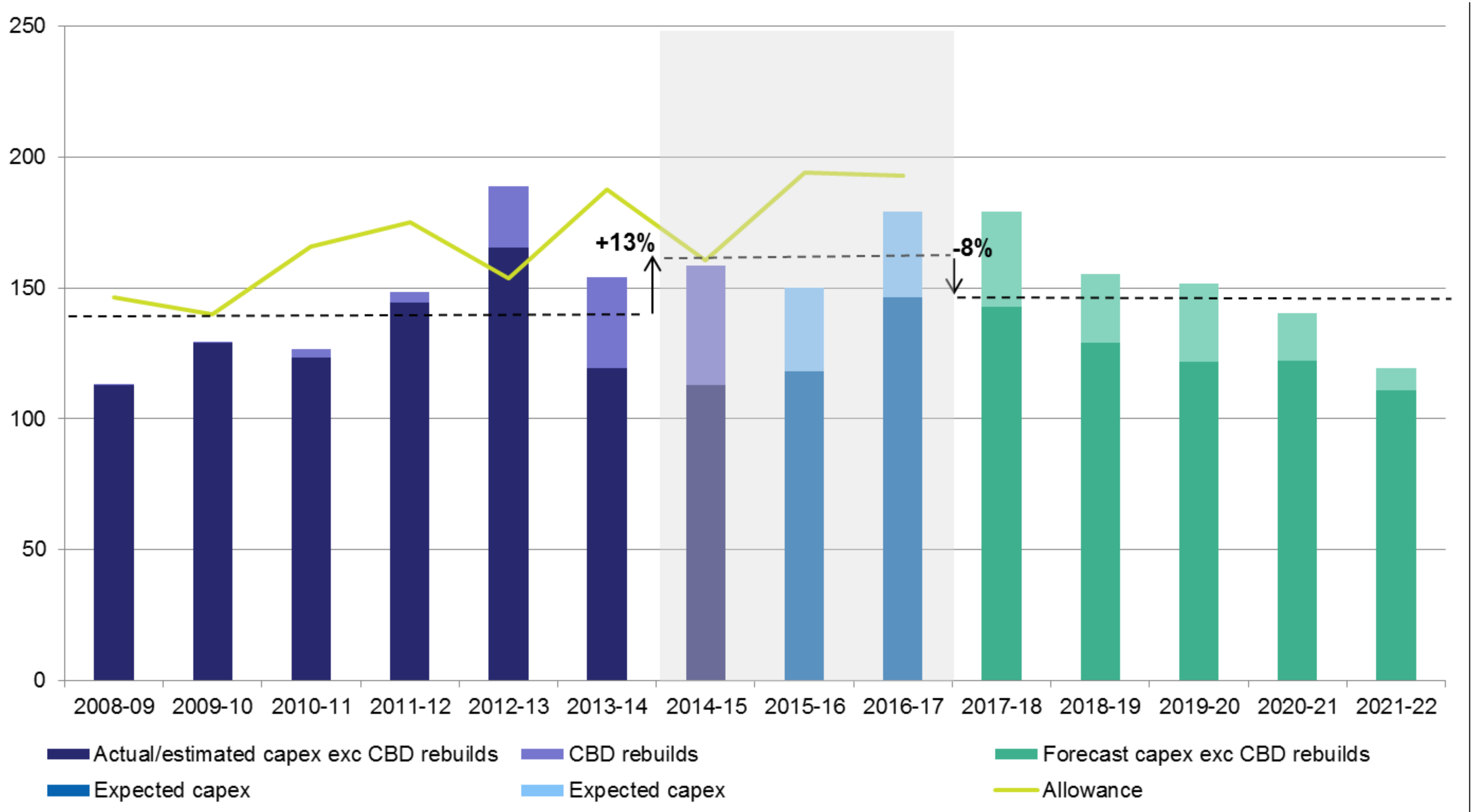
OUTPUT: FUEL CONSUMPTION - OMAN



RAMBOLL

OUTPUT: CAPITAL EXPENDITURE - AUSTRALIA



REGULATED ENTITIES AND THE REGULATOR

REGULATED ENTITIES AND THE REGULATOR

'…a safe, reliable and efficient supply of electricity…'

REGULATED ENTITIES AND THE REGULATOR

هيئة تنظيم الكهرباء - عمان
AUTHORITY FOR ELECTRICITY REGULATION, OMAN

AER
AUSTRALIAN ENERGY REGULATOR

مكتب التنظيم و الرقابة
Regulation & Supervision Bureau

'...protect the interests of existing and future consumers...'

OFWAT
Water today, water tomorrow

هيئة تنظيم الكهرباء والإنتاج المزدوج
ELECTRICITY & COGENERATION REGULATORY AUTHORITY

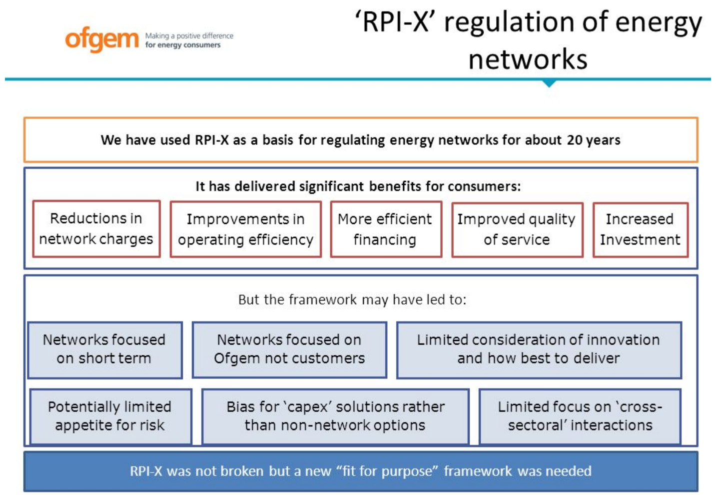
ofgem

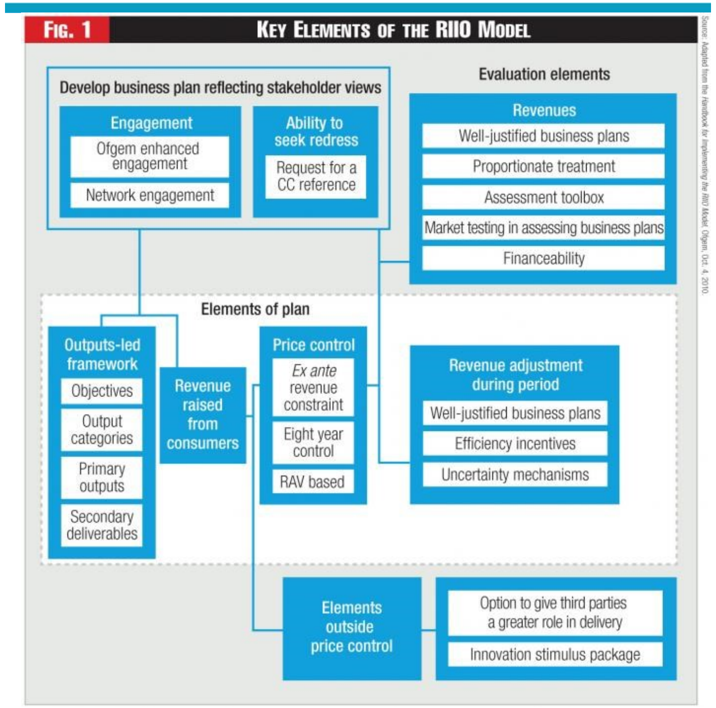
REGULATED ENTITIES AND THE REGULATOR

- Businesses are a natural monopoly
- Regulator encourages efficiency
- Protect customers

- Complex modelling may not produce a 'better' answer

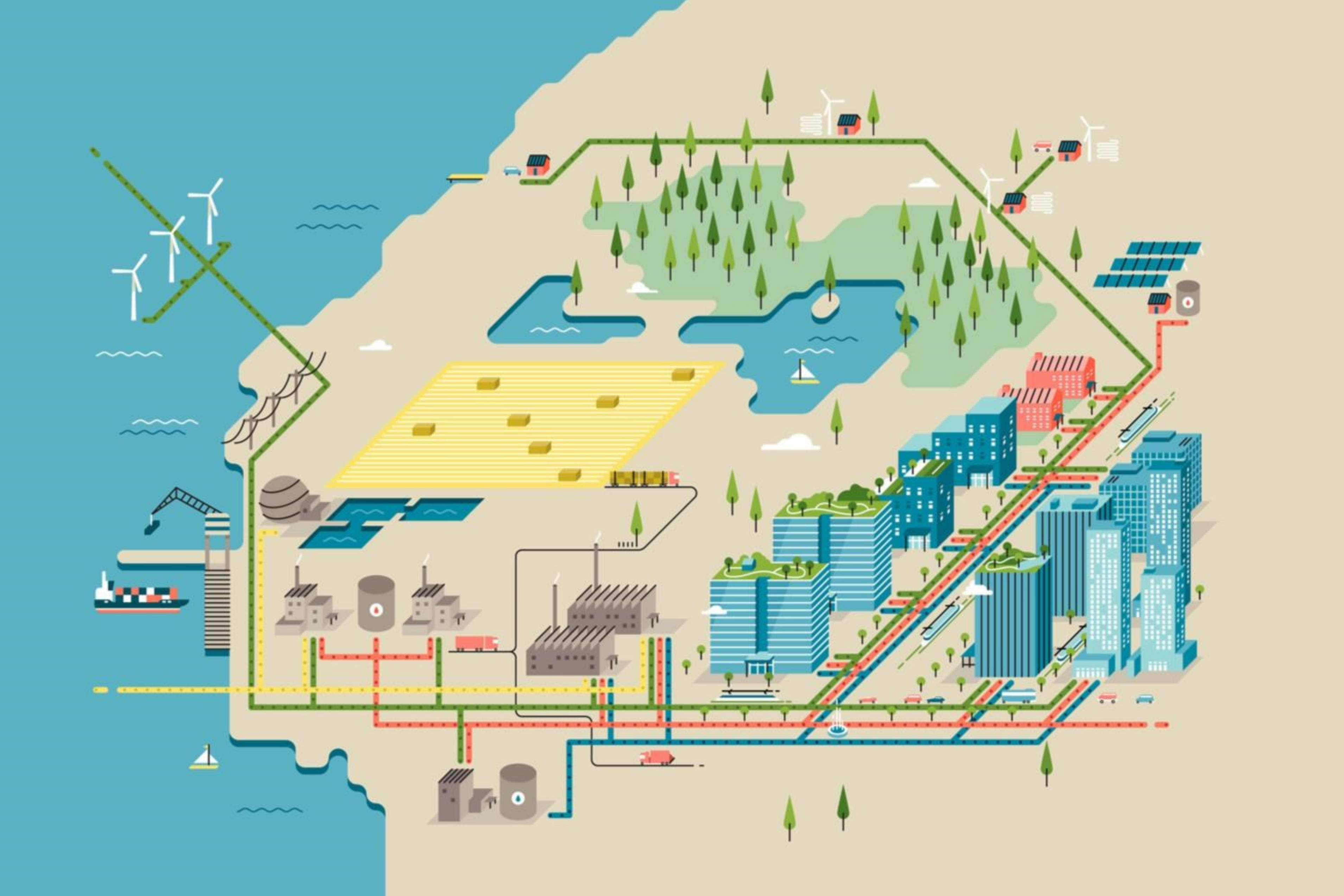
- Has to be understood the 'black box' Totex





RAMBOLL

INNOVATION



- Surplus biomass for CHP plant
- Surplus straw for CHP plant
- Offshore wind farm
- Large building
- Residential building
- Harbour, unloading of biomass
- Wastewater treatment and biogas plant
- Solar heating plant and heat storage
- Distant building w/solar PV
- Outskirt building w/heat pump, solar PV and wind turbine
- CHP plant fuelled by gas, straw, wood, city waste + heat storage
- District heating/cooling plant + cold water storage
- Industry with process energy and surplus heat
- Electricity
- District heating
- District cooling
- Gas

INNOVATION

Electricity NIC project

Project:
Transition

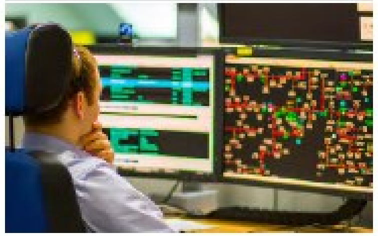
Company name:
SSE Networks (SSEN)

The concept:
To test technical and commercial solution to resolve constraints on the distribution network.

NIC funding awarded:
£13.1 million*

Additional company contribution/ external funding:
£1.5 million from SSEN.

Period of project:
5 years



The project will aim to:

- Test market models for the trading of flexible network services.
- Create the IT interface to facilitate the markets.
- Release additional network capacity for low carbon technology connections.

Electricity NIC project

Project:
Fusion

Company name:
SP Energy Networks (SPEN)

The concept:
To test a technical and commercial solution developed in Europe to resolve constraints on the distribution network.

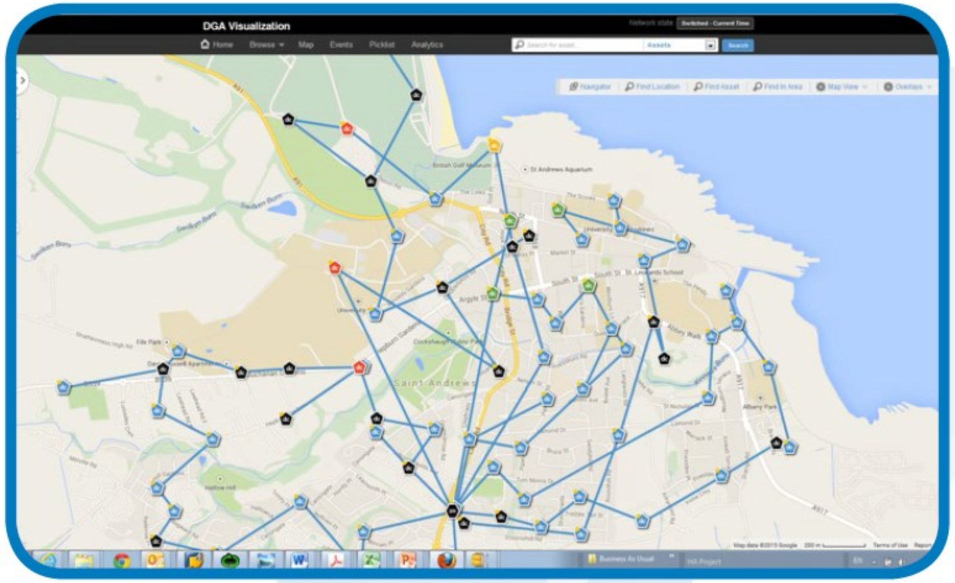
NIC funding awarded:
£5.3 million*

Additional company contribution/ external funding:
£0.6 million from SPEN

Period of project:
5 years

The project will aim to:

- Test a European market model for the trading of flexible network services.
- Create the IT infrastructure to facilitate the market.
- Release additional network capacity for low carbon technology connections.



Common Information Model

Funding Mechanism	Network Innovation Allowance (NIA)
Starts - Ends	May 2016 - August 2018
Estimated Expenditure	£750k
Research Area	Network Operations, Comms & IT

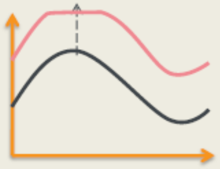
Objective(s)

The objectives of this project are to:

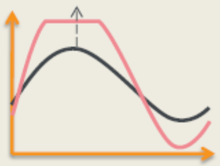
1. Extend the existing Integrated Network Model for 11kV to export data in CIM format;
2. Create a replicable process to combine data for 33kV and 66kV and 132kV networks to identify data quality issues and provide a CIM format output; and
3. Test the benefits that arise from creating a CIM format network model in terms of software adoption, information exchange and system interfaces.

Using storage to **manage peak demands**, or **smooth renewables output** can defer or avoid the drivers of conventional reinforcement

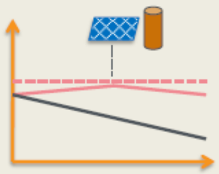
Increased electricity demand



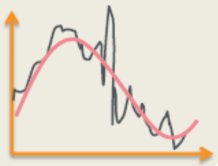
Higher peak demands



Thermal & voltage constraints



Less predictable load & gen cycles



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INNOVATION

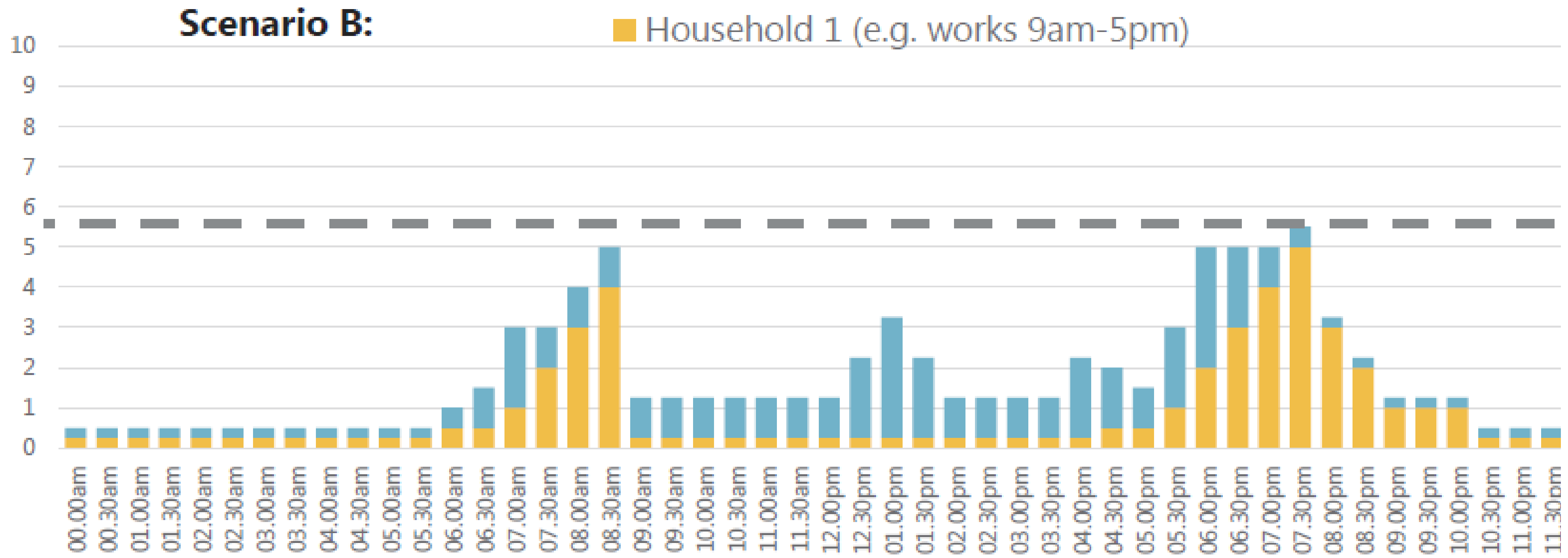
Document Number	Document Title	Date	View Document
CLNR-L267	Academic paper: A probabilistic approach to combining smart meter and electric vehicle charging data to investigate distribution network impacts	1-Nov 2015	View >>
CLNR-L265	Academic paper: Fostering active network management through SMEs' practises	20-Aug 2015	View >>
CLNR-G026	Project Closedown Report	31-Mar 2015	View >>
CLNR-L246	Developing the smarter grid: the role of domestic and small and medium sized enterprise customers	31-Mar 2015	View >>
CLNR-L248	Developing the smarter grid: optimal solutions for smarter network businesses	31-Mar 2015	View >>
CLNR-L247	Developing the smarter grid: the role of industrial and commercial and distributed generation customers	31-Mar 2015	View >>

RAMBOLL

ISSUES WHEN TRAILING NEW MATHEMATICAL TECHNIQUES

ISSUES WHEN TRAILING NEW MATHEMATICAL TECHNIQUES

Under scenario B, the households have two completely different consumption patterns. Although the overall amount used in a day is the same, assess to HH electricity use data shows that the peak capacity is now only 5.5kWh per half hour. The DNO is therefore able to build a smaller and cheaper network.



- Standard domestic connection in the UK is 100A 35mm² Concentric Aluminium

ISSUES WHEN TRAILING NEW MATHEMATICAL TECHNIQUES

- Equipment standardisation reduces costs (for the business) but also limits options

Voltage	Conductors			Construction			Current Rating (Laid Direct)						Current Rating Ducted)						Positive & Negative Sequence (Ohmic)				
							Continuous		Cyclic		Emergency		Continuous		Cyclic		Emergency						
(kV)	mm^2/ in^2	Mat	No.	Insulation	Sheath	Protection	Amps	kVA	Amps	kVA	Amps	kVA	Amps	kVA	Amps	kVA	Amps	kVA	DC Resistance Ω/km (20°C)	AC Resistance at max insulator temp Ω/km	Reactance Ω/km	Neutral Resistance Ω/km	Earth Resistance Ω/km
Waveform - 3c Al/Cu																							
0.4	35	Al	3	XLPE	Cu		125	87	143	99	151	105	104	72	118	82	126	87	0.868	1.078	0.076	0.433	0.433
0.4	70	Al	3	XLPE	Cu		185	128	211	146	224	155	154	106	175	121	186	129	0.443	0.558	0.074	0.320	0.320
0.4	95	Al	3	XLPE	Cu		235	163	268	186	284	197	195	135	222	154	236	164	0.320	0.398	0.073	0.320	0.320
0.4	120	Al	3	XLPE	Cu		255	177	291	201	309	214	212	147	241	167	256	177	0.253	0.320	0.074	0.164	0.164
0.4	185	Al	3	XLPE	Cu		335	232	382	265	405	281	278	193	317	220	336	233	0.164	0.205	0.073	0.164	0.164
0.4	300	Al	3	XLPE	Cu		435	301	496	344	526	365	361	250	412	285	437	303	0.100	0.126	0.073	0.164	0.164

ISSUES WHEN TRAILING NEW MATHEMATICAL TECHNIQUES

PRODUCED BY THE OPERATIONS DIRECTORATE OF ENERGY NETWORKS ASSOCIATION

ena energynetworks association

Engineering Report 131

Issue 2 2012

Analysis package for assessing generation security capability – Users' guide

Intermittent Generation	Edit Data		
Persistence Tm (days, hours, minutes)	1 days	6 hours	0 minutes
Status On / Off	On		
Filename	Wind Farm.txt		Persistence Tm
Nameplate Rating (MW)	0	Value is given by file	1.25 days
Interval (min)	0	Value is given by file	30 hours
Number of States	101		1800 minutes

Figure 7 — Input data for Intermittent Generation

- The impact on customers leads to a natural conservatism / contingent allowance
- The impacts may not be immediately evident, especially if related to emergency (ie frequency response, spinning reserve)

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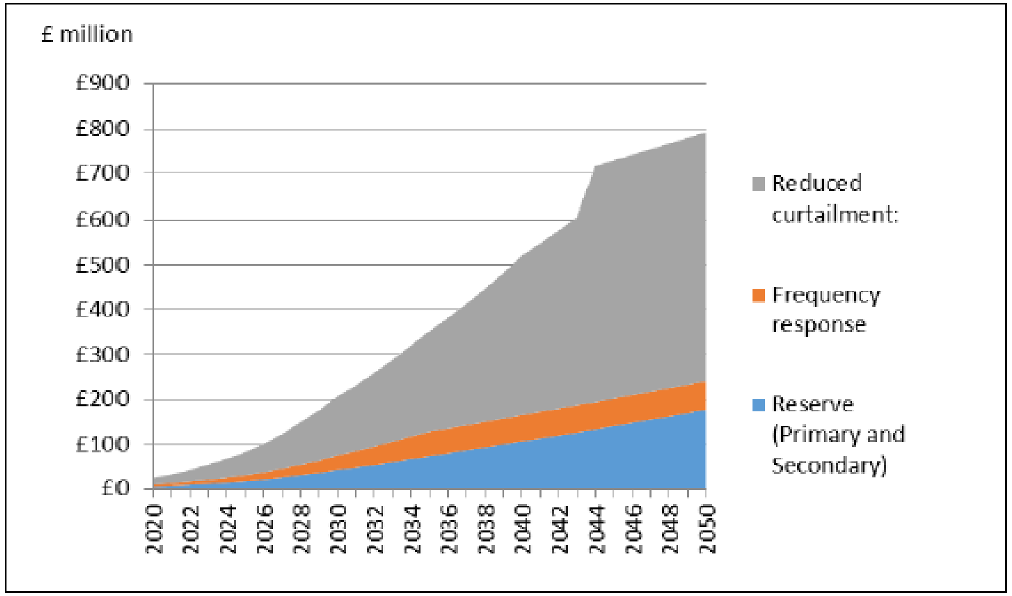
THE FUTURE

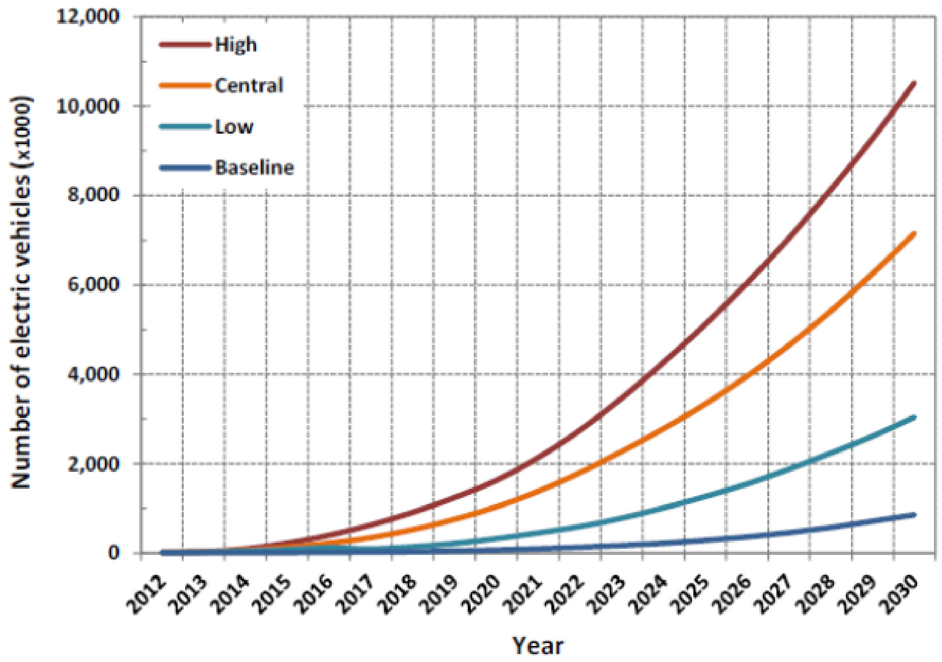
THE FUTURE

Figure 7.1 Total revenue generated by EV services to the electricity grid



- Electric vehicle uptake and the impact on electricity networks

DfT's trajectories for electric vehicle uptake[18]



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THE FUTURE

Figure 1:
Case Study Timelines

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THE FUTURE

Case study
UK Power Networks Flexibility Tenders

Case study
Customer Load Active System Services (CLASS)

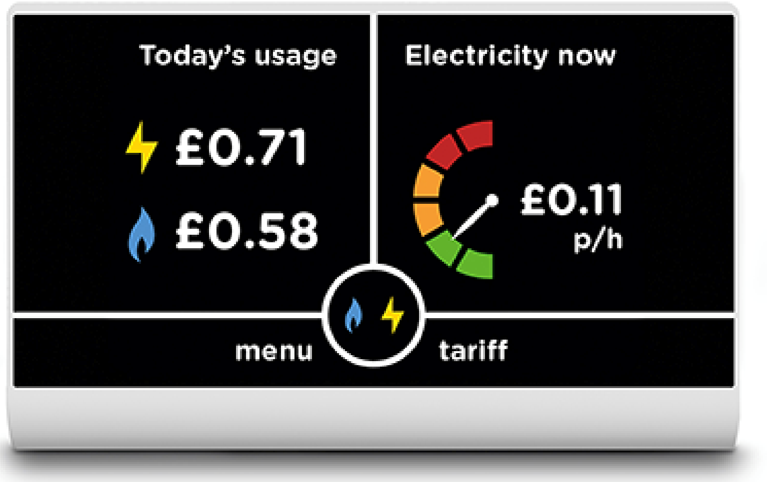
Case study
SP Energy Networks Active Network Management

Case study
Western Power Distribution Project ENTIRE

Case study
Developing and Testing DSO Models

Case study
SSEN Constraint Managed Zones

THE FUTURE



- Smart meters

SUMMARY

SUMMARY

- There are opportunities for improving decision making within the energy utilities
- As regulated entities, there is a licence obligation to be efficient for the end user customer
- Data access (smart meters) in distributed networks will provide unprecedented level of detail
- Innovation is now encouraged by the regulator in the UK, and this innovation does flow overseas into other jurisdictions
- DSOs – already implemented in the Nordic regions. Accounting for more end user activity.

THANK YOU

RAMBØLL