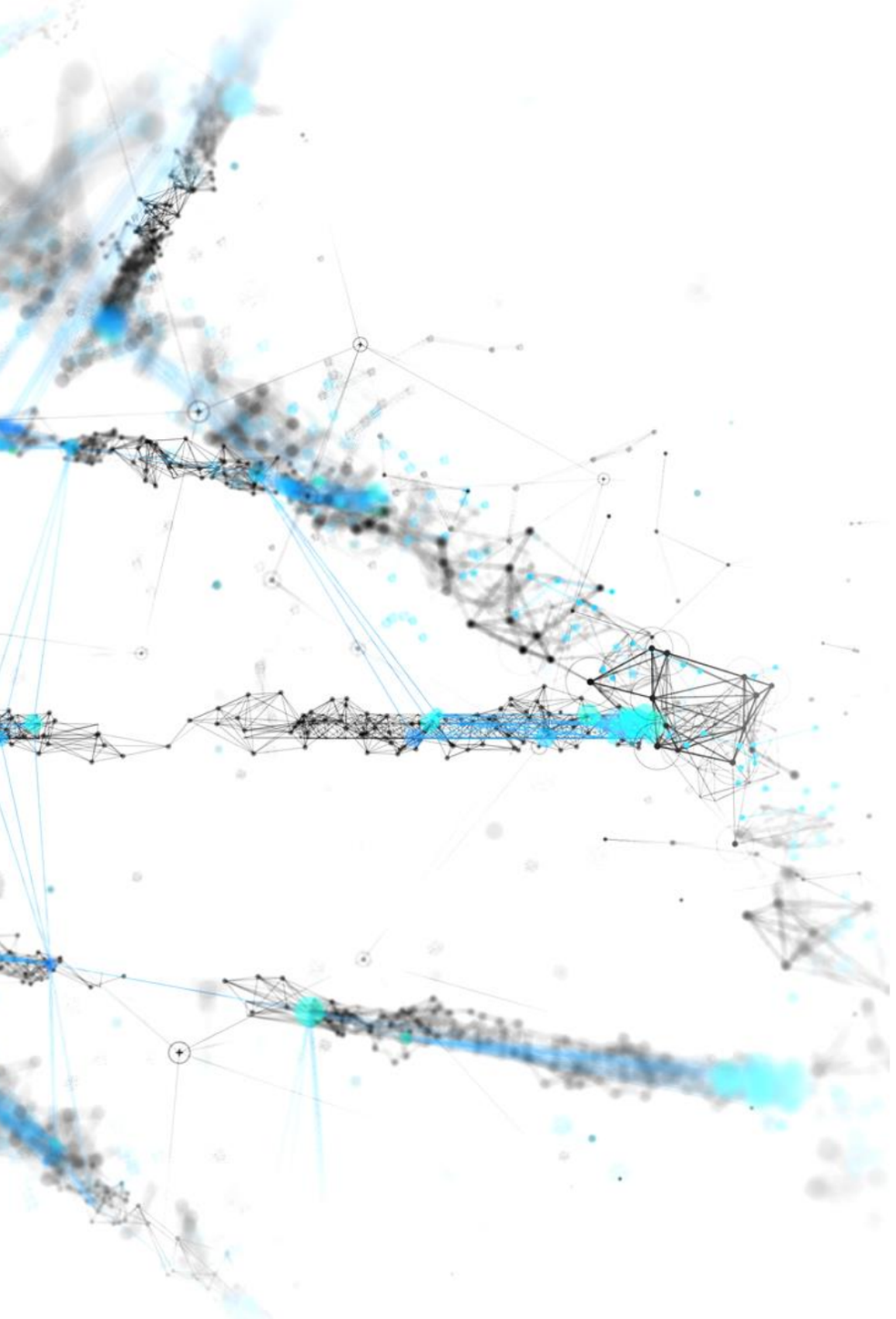

@EdwardOughton #PTC19

Building a Digital Twin:

Testing the Effectiveness of Telecommunication Policies in a Virtual World

Edward J. Oughton

University of Oxford

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PACIFIC TELECOMMUNICATIONS COUNCIL

PTC'19 | FROM PIPES TO PLATFORMS

20–23 January 2019 | Honolulu, Hawaii

Summary

1. Decisions
2. Currently poor transparency and reproducibility
3. Digital Twin: Holds promise...

(...*if produced in the right way*)

Digital infrastructure **decisions** are hard

Operators **don’t** want to share **data**

We have few existing **open-source** models

Model code isn’t shared, so **can’t** be independently **validated**

Existing models **don't** have a **GUI** and are hard for non-technical users

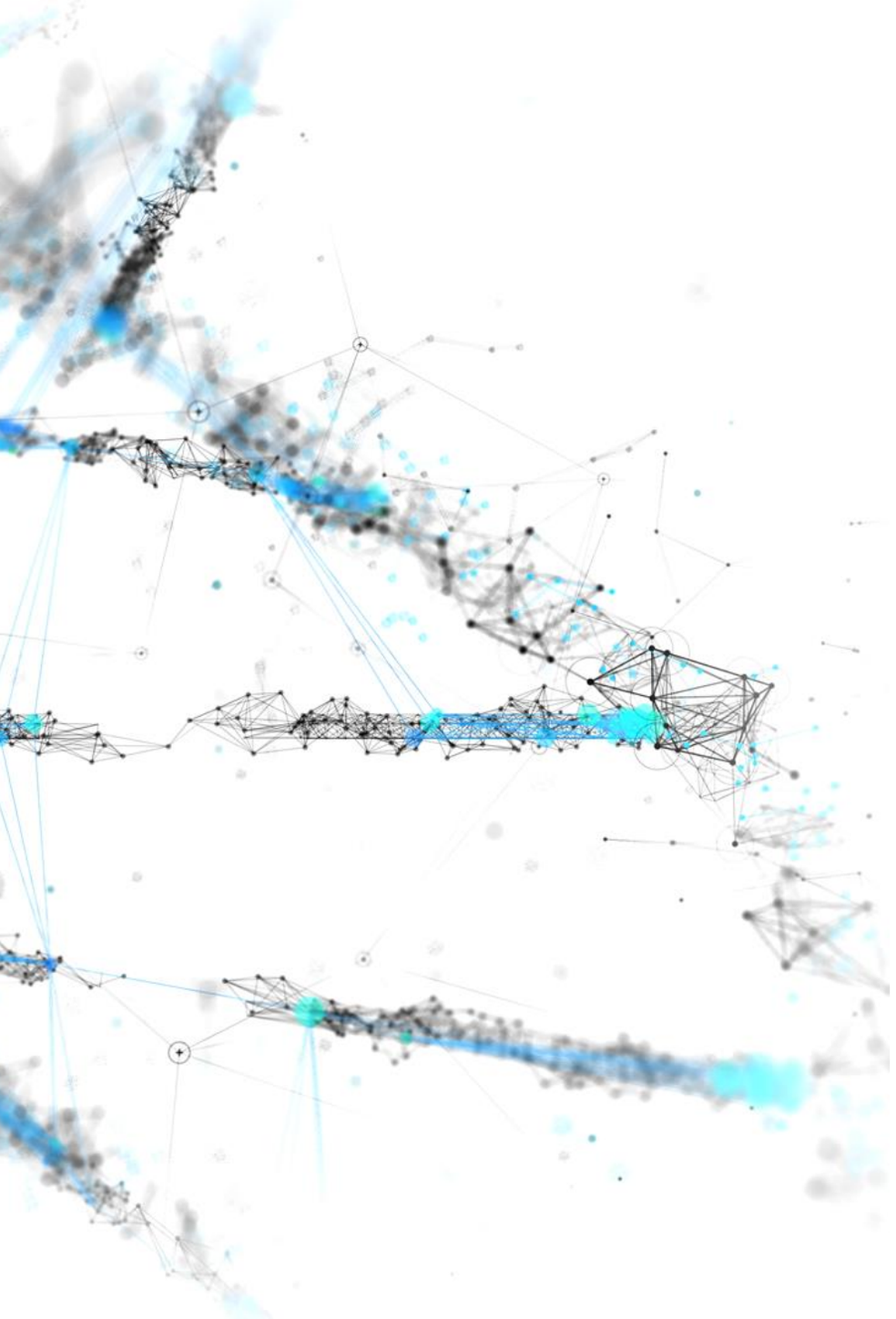
Disagreement on FTTP Targets

'…*I will set a target to see full-fibre connections being available to **15 million** premises, that's the majority of homes and businesses, by **2025**.*'

Hammond, P. MP, Chancellor of the Exchequer (CBI Speech)

*'We want to reach **10m** premises by the **mid-2020s**, and believe we can ultimately fully-fibre the majority of the UK under the right conditions.'*

Clive Selley, CEO Openreach (Response to CBI Speech)

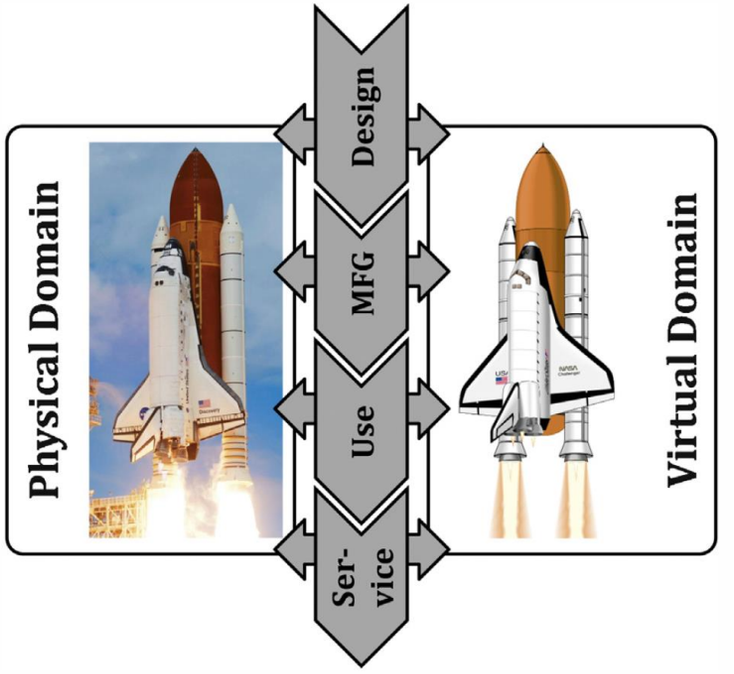


What is a Digital Twin?

The Digital Twin Concept

'an integrated multi-physics, multi-scale, probabilistic simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its flying twin.'

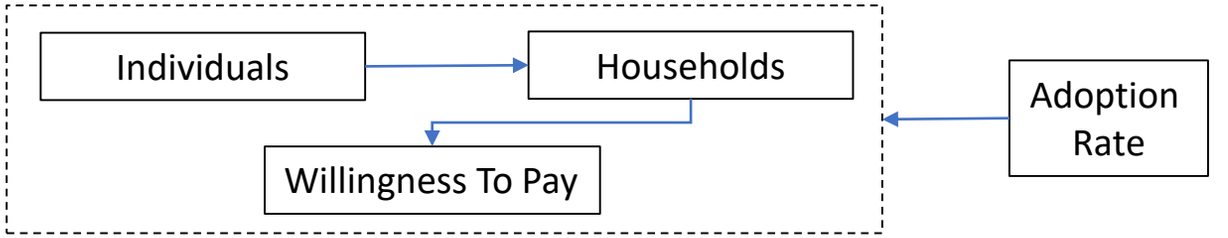
(NASA, 2010)



Schleich et al. 2017

Method

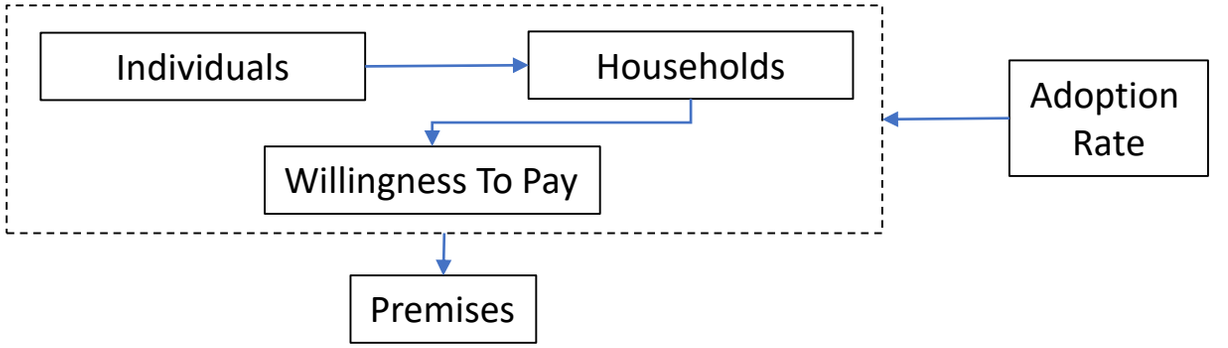
Scenarios



Method

Scenarios

Household allocation

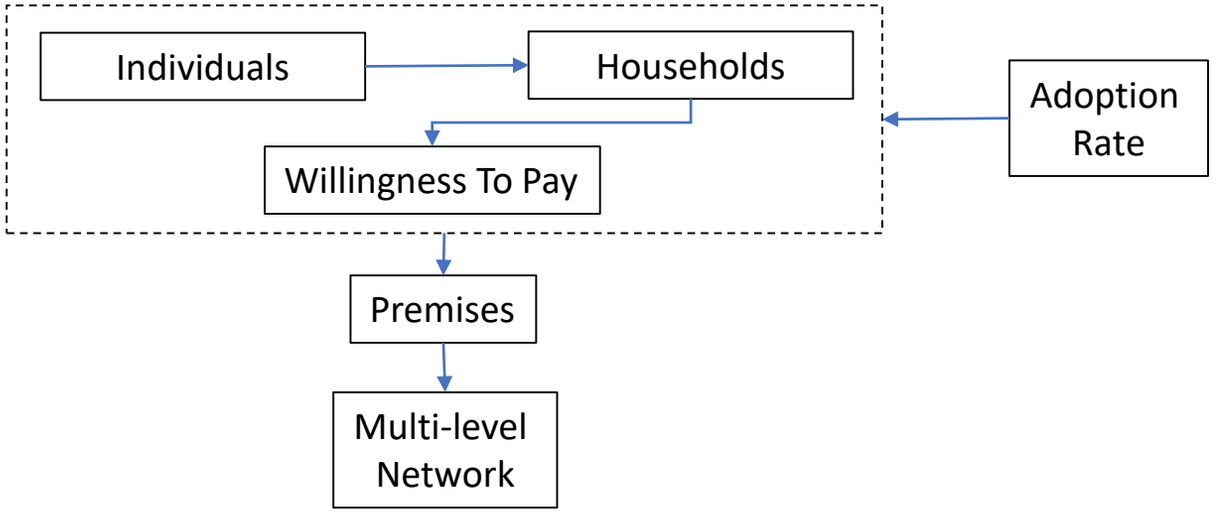


Method

Scenarios

Household allocation

Network synthesis



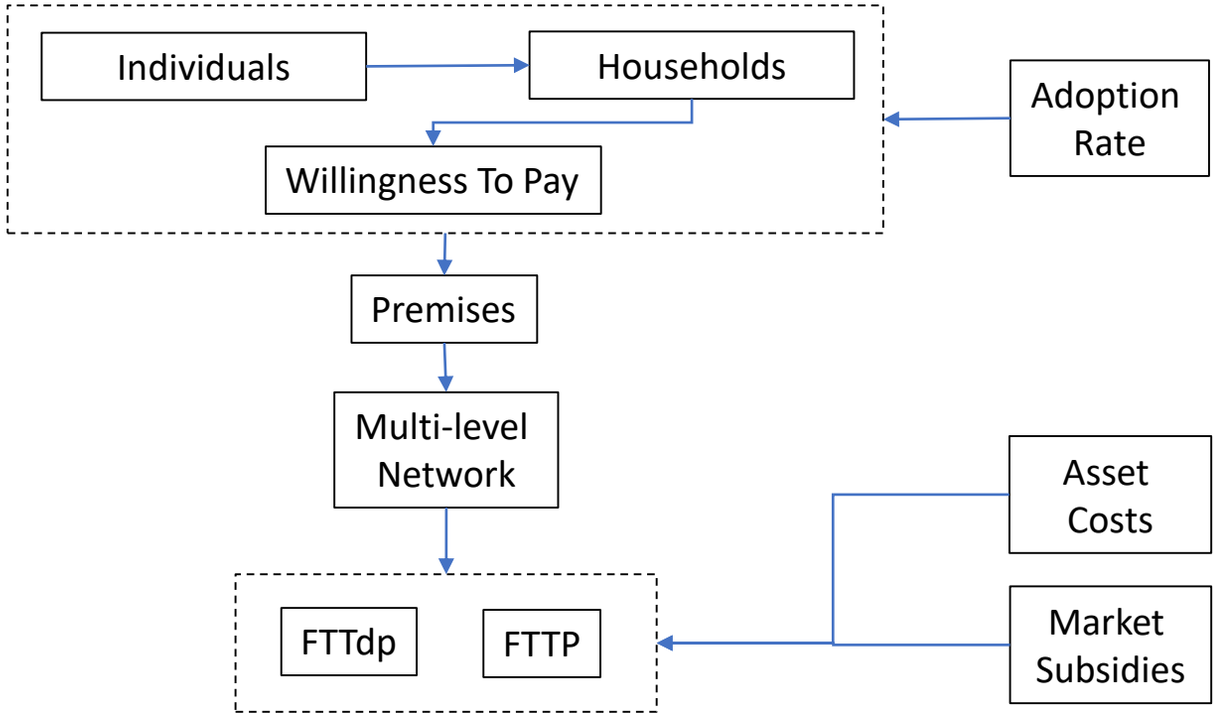
Method

Scenarios

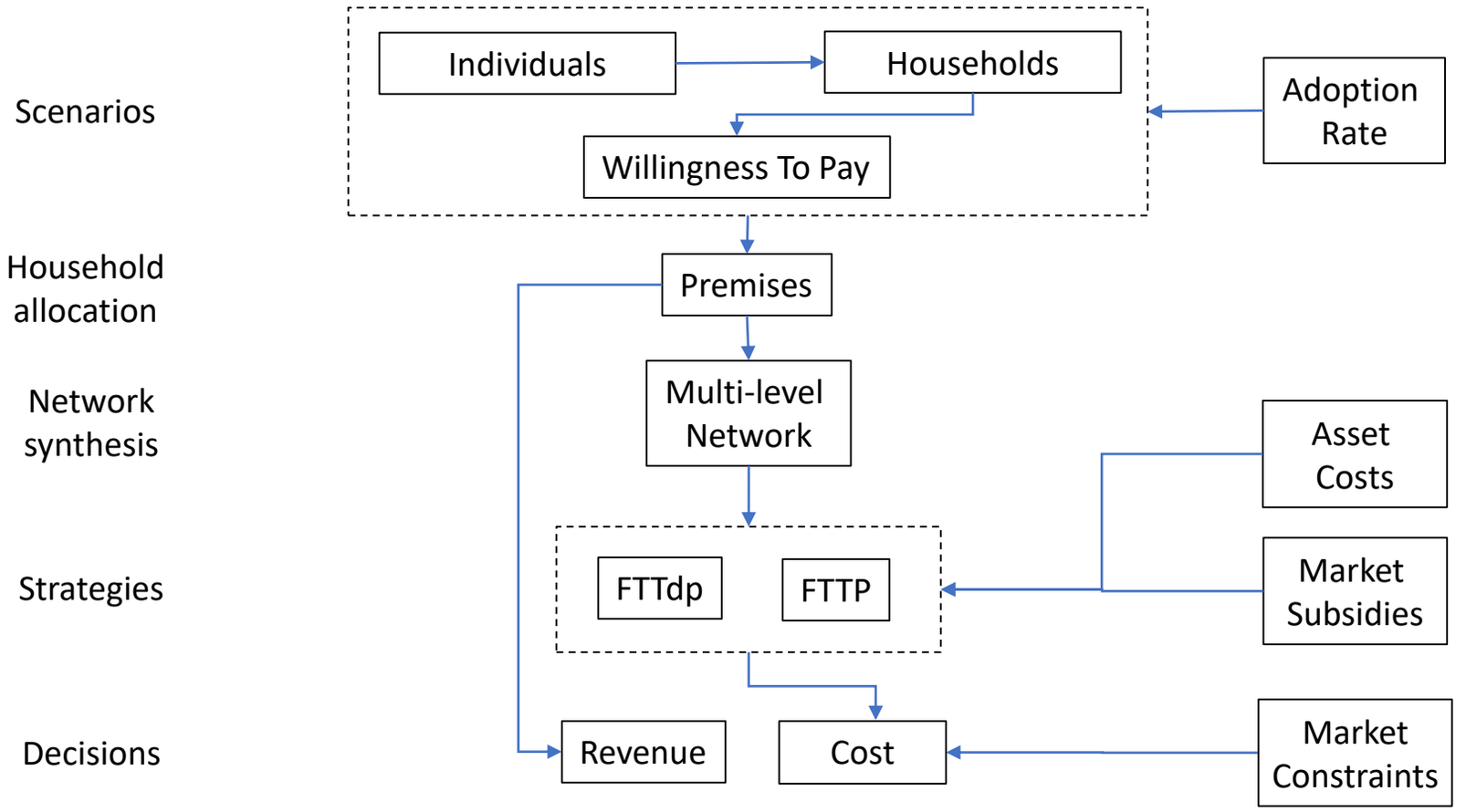
Household allocation

Network synthesis

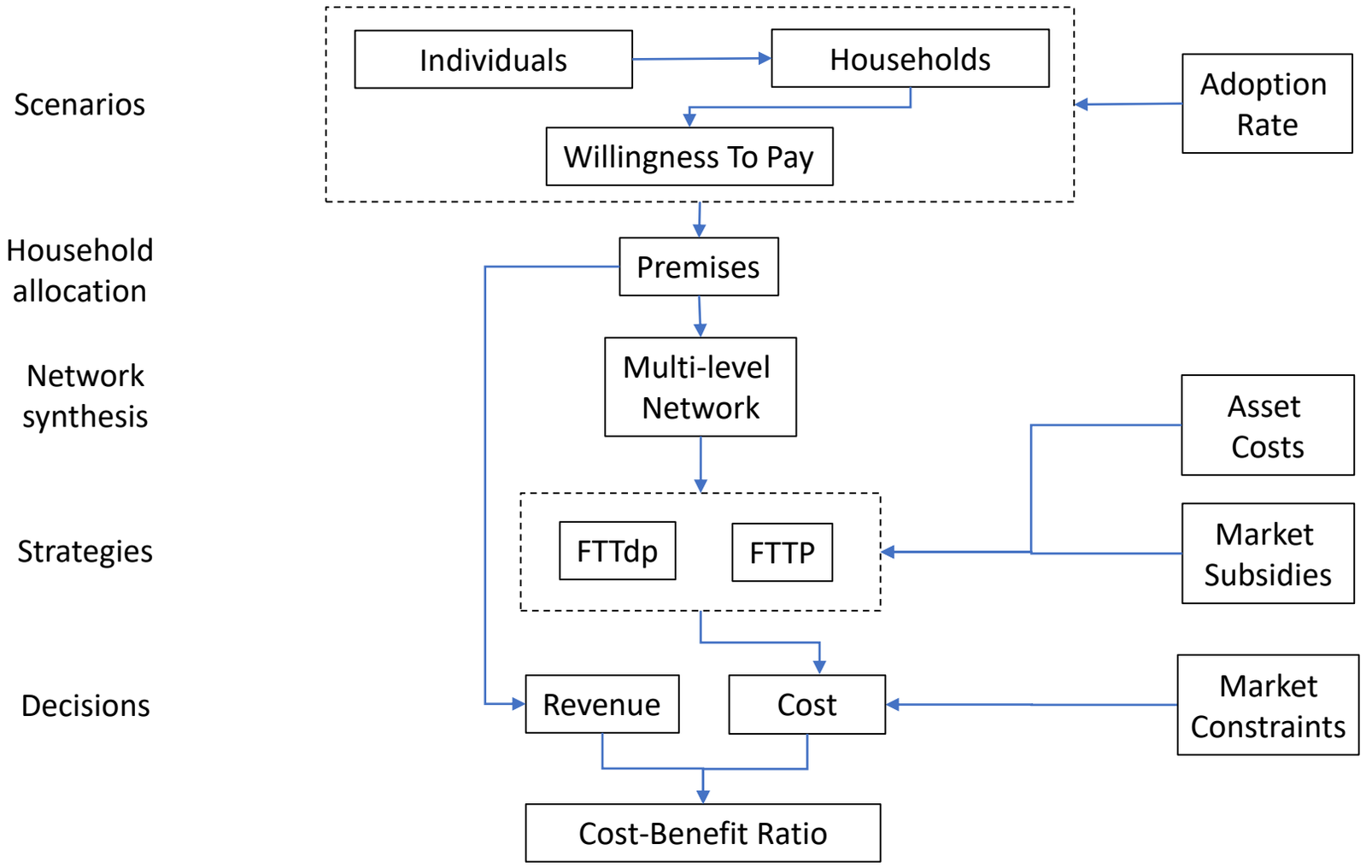
Strategies



Method


Scenarios
Household allocation
Network synthesis
Strategies
Decisions
Individuals
Households
Adoption Rate
Willingness To Pay
Premises
Multi-level Network
Asset Costs
FTTdp
FTTP
Market Subsidies
Revenue
Cost
Market Constraints

Method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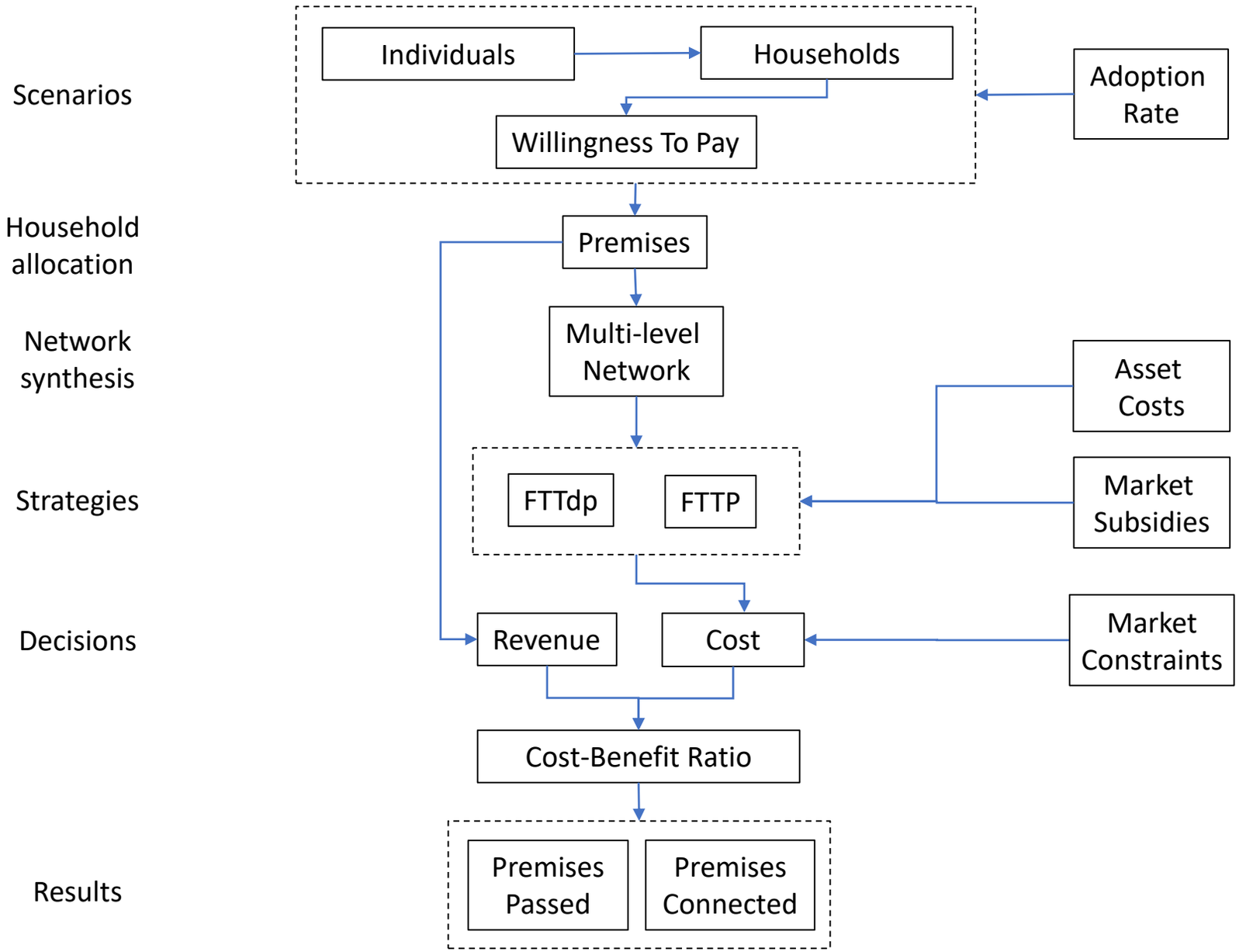
Market Subsidies
Revenue
Cost
Market Constraints
Cost-Benefit Ratio

Method


Scenarios
Household allocation
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Decisions
Results
Individuals
Households
Adoption Rate
Willingness To Pay
Premises
Multi-level Network
Asset Costs
FTTdp
FTTP
Market Subsidies
Revenue
Cost
Market Constraints
Cost-Benefit Ratio
Premises Passed
Premises Connected

Method: High-Resolution Demand Data

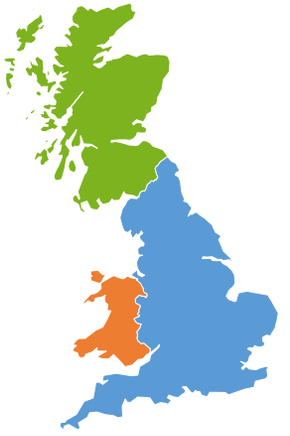
Age

a_i

Socio-economic status

b_i

Nation



c_i

Urban-rural

d_i

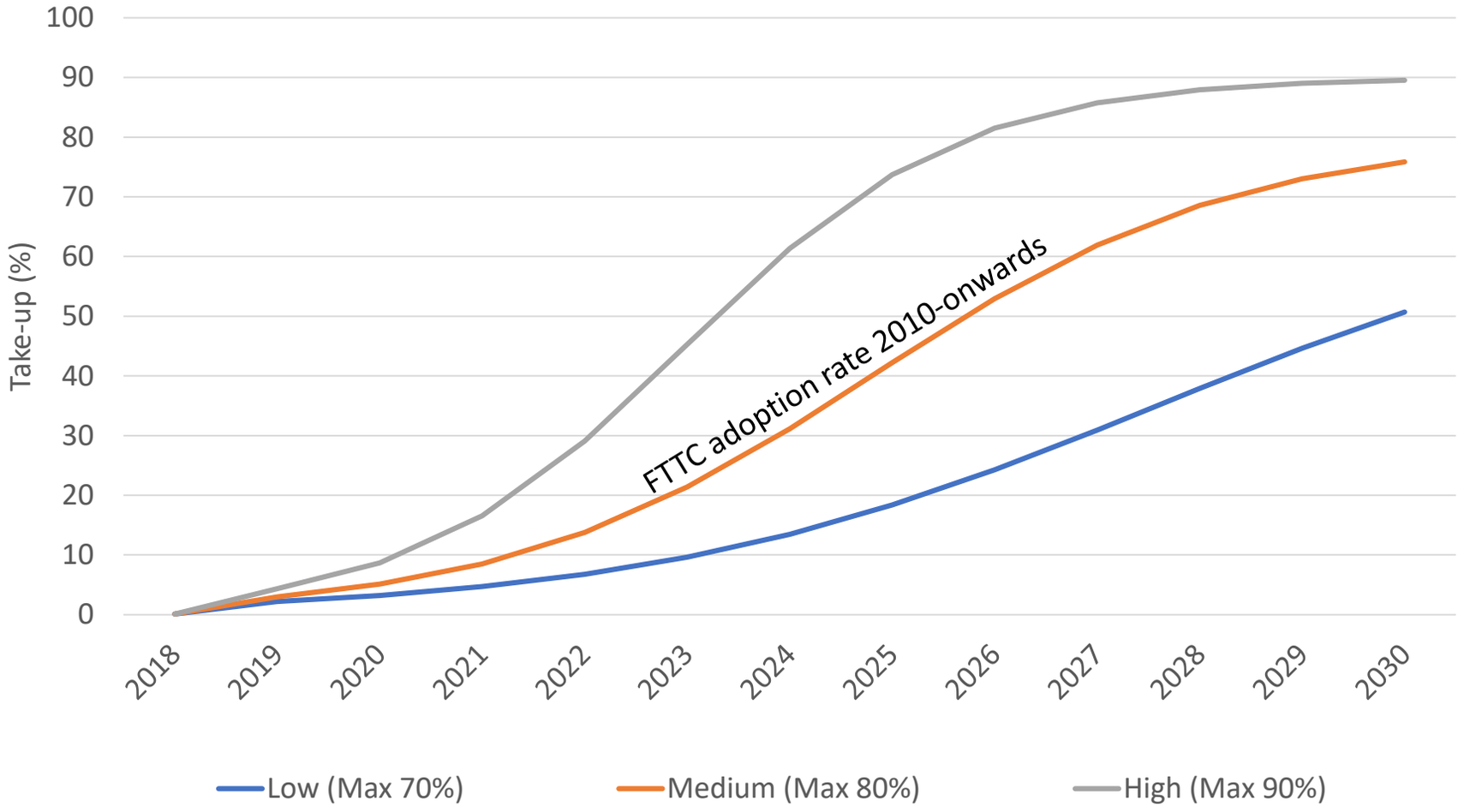
Gender

e_i

Propensity to adopt $(p_i) = a_i \cdot b_i \cdot c_i \cdot d_i \cdot e_i$

*Probabilities taken from the **Ofcom (2017) Technology Tracker** for propensity to adopt **>30 Mbps***

Method: Scenario Adoption

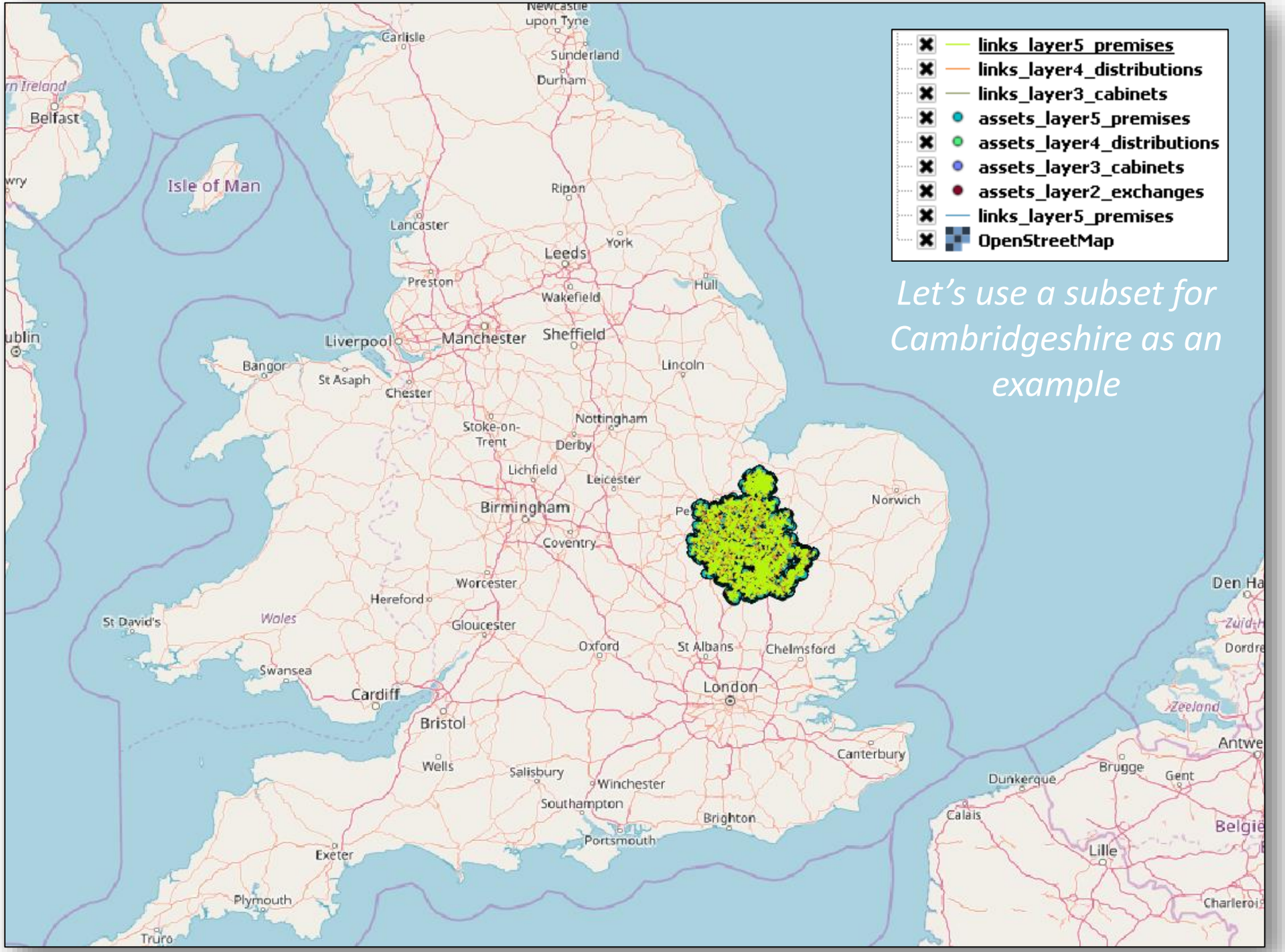


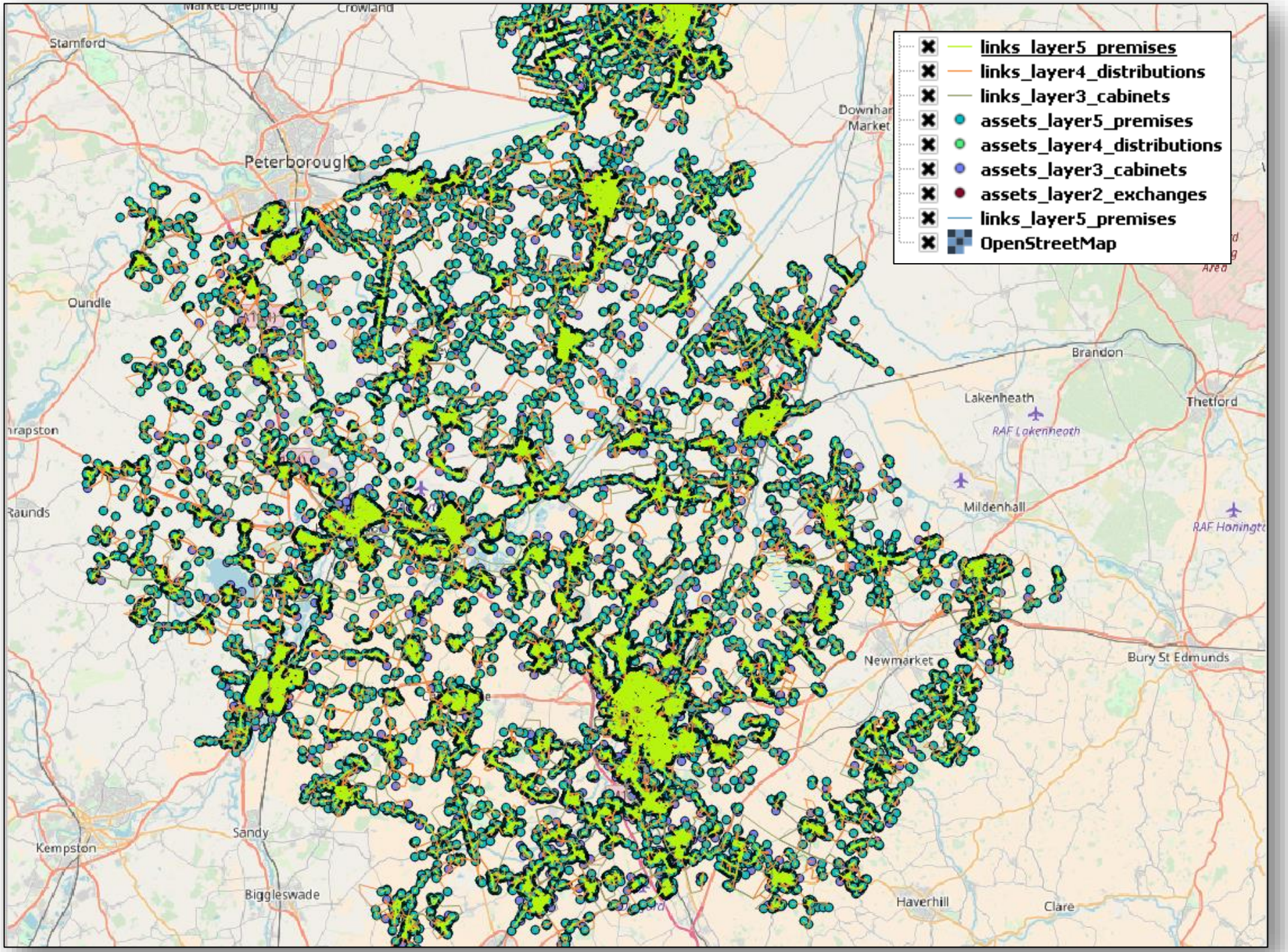
Method: Synthetic Network Structure

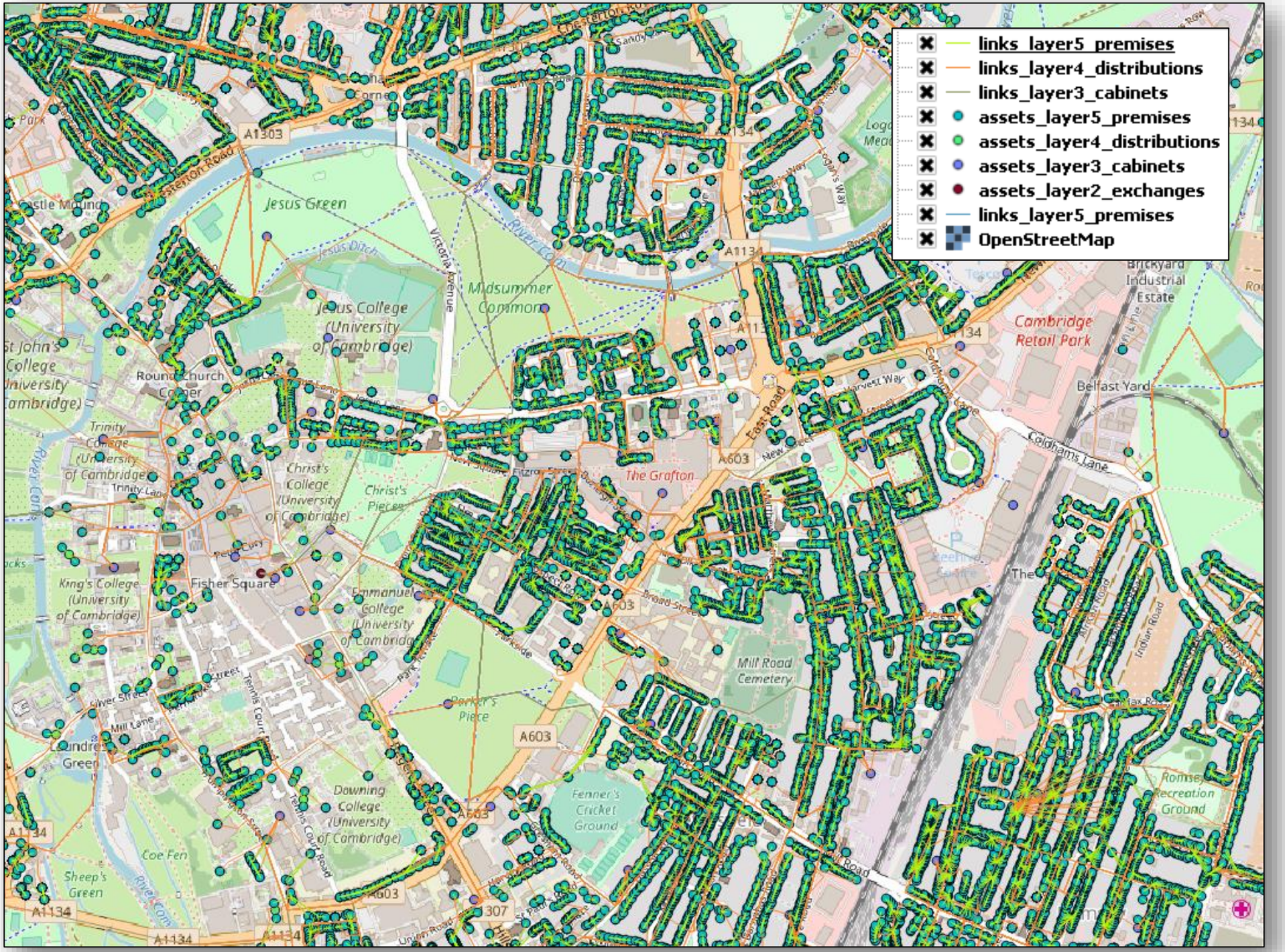
Data category	Data	Source	Year
Supply-side	Postcode to exchange data	Openreach	2011, 2013
Supply-side	Postcode to cabinet data	Openreach	2011, 2013
Boundaries	Postcode polygons	Ordinance Survey	2012 (October)
Supply-side	Broadband technology by postcode	Ofcom	2017
Boundaries	Local Authority District polygons	ONS	2016
Supply-side	Urban Local Authority Districts by city and size	Analysys Mason	2008
Demand-side	Premises points data	Ordinance Survey	2016
Supply-side	Exchange points	SamKnows	2017

Method: Synthetic Network Structure

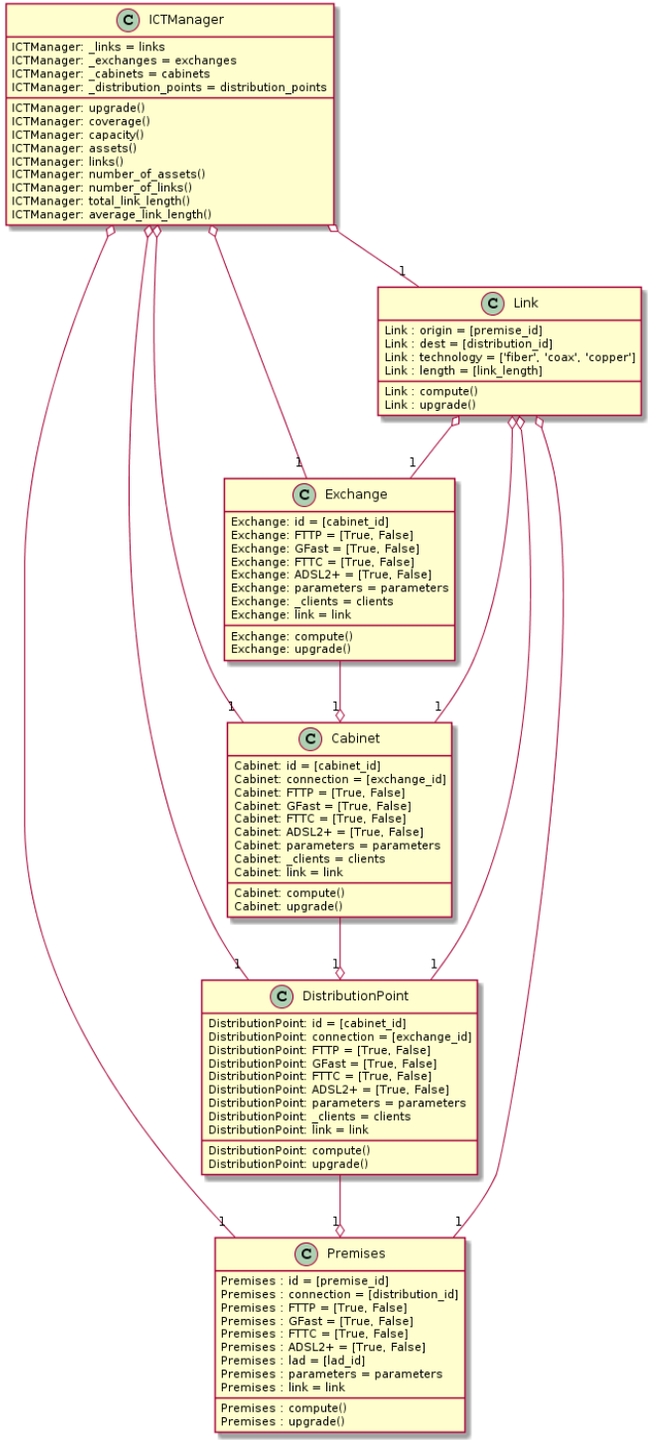
Geotype	Classification	Exchanges	Average lines per exchange	Cabinets	Average lines per cabinet	Distribution points	Average lines per distribution point	Average line length (km)
Inner London	Inner London	86	16,812	2,892	500	172,118	8.4	1.24
>500k pop	Major City (pop = 500k+)	204	15,512	6329	500	376,721	8.4	1.78
>200k pop	City (pop = 200k+)	180	15,527	5,590	500	332,713	8.4	1.8
>20k lines (a)	>20,000 lines, <2km from the exchange	167	17,089	6,008	475	365,886	7.8	1.5
>20k lines (b)	>20,000 lines, >2km from the exchange	167	10,449	4,362	400	223,708	7.8	4.83
>10k lines (a)	>10,000 lines, <2km from the exchange	406	10,728	9,679	450	604,925	7.2	1.4
>10k lines (b)	>10,000 lines, >2km from the exchange	406	3,826	4,142	375	215,740	7.2	4.0
>3k lines (a)	>3,000 lines, <1km from the exchange	1,003	2,751	13,455	205	493,569	5.6	0.73
>3k lines (b)	>3,000 lines, >1km from the exchange	1,003	3,181	22,227	144	570,745	5.6	4.83
>1k lines (a)	>1,000 lines, <1km from the exchange	1,230	897	5,974	185	246,555	4.5	0.62
>1k lines (b)	>1,000 lines, >1km from the exchange	1,230	935	9,343	123	257,043	4.5	4.09
<1k lines (a)	<1,000 lines, <1km from exchange	2,302	190	0	0	130,706	3.4	0.52
<1k lines (b)	<1,000 lines, >1km from exchange	2,302	305	0	0	209,571	3.4	4.26
	National Figure:	5,578	4,886	90,000	303	4,200,000	6.5	2.33


links_layer5_premises
links_layer4_distributions
links_layer3_cabinets
assets_layer5_premises
assets_layer4_distributions
assets_layer3_cabinets
assets_layer2_exchanges
links_layer5_premises
OpenStreetMap
Let's use a subset for Cambridgeshire as an example
Belfast
Isle of Man
Carlisle
Newcastle upon Tyne
Sunderland
Durham
Ripon
Lancaster
Leeds
York
Preston
Hull
Wakefield
Liverpool
Manchester
Sheffield
Bangor
St Asaph
Chester
Lincoln
Stoke-on-Trent
Nottingham
Derby
Lichfield
Leicester
Birmingham
Norwich
Coventry
Worcester
Hereford
Wales
St David's
Gloucester
Oxford
St Albans
Chelmsford
Swansea
Cardiff
London
Bristol
Canterbury
Wells
Salisbury
Winchester
Southampton
Brighton
Portsmouth
Exeter
Plymouth
Truro
Dunkerque
Calais
Brugge
Gent
Lille
Zeeland

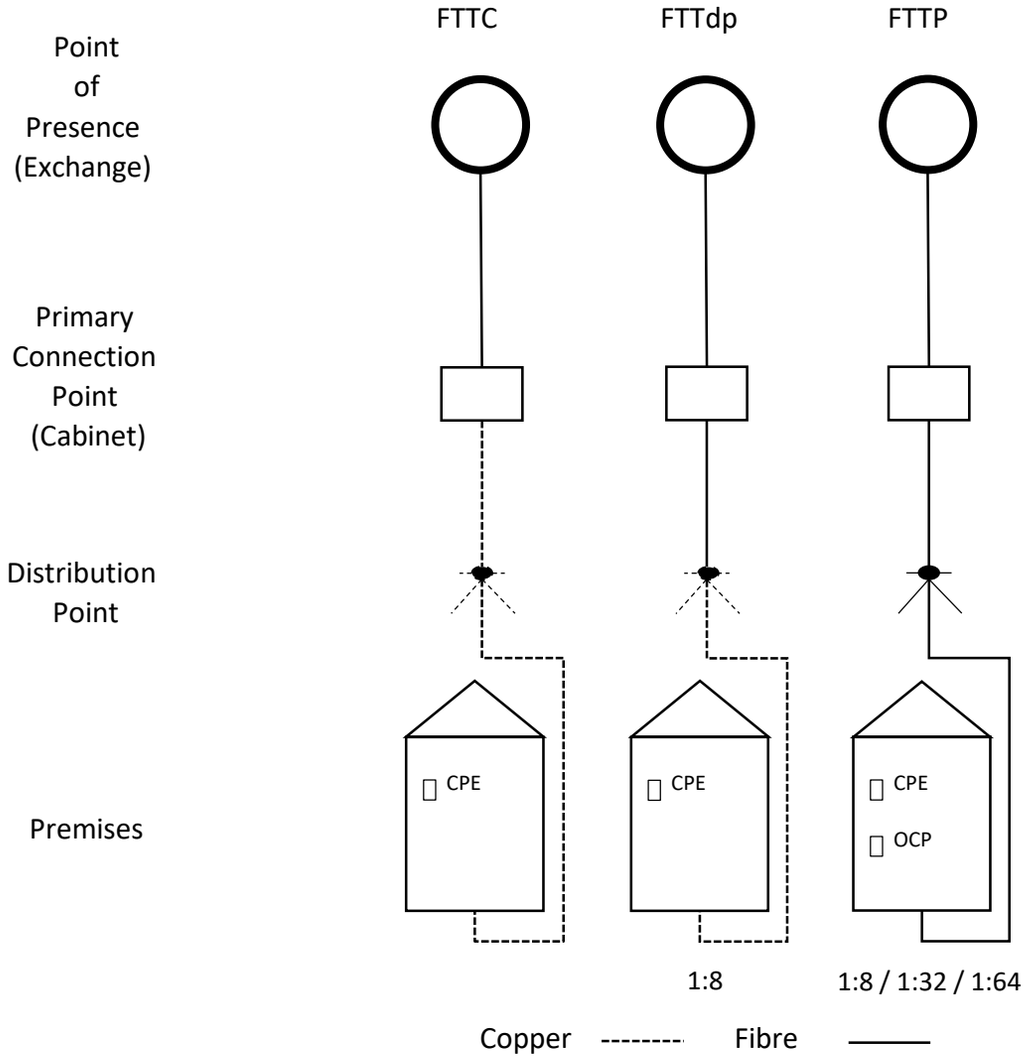

links_layer5_premises
links_layer4_distributions
links_layer3_cabinets
assets_layer5_premises
assets_layer4_distributions
assets_layer3_cabinets
assets_layer2_exchanges
links_layer5_premises
OpenStreetMap
Stamford
Peterborough
Crowland
Market Deeping
Downham Market
Oundle
Brandon
Lakenheath
RAF Lakenheath
Thetford
Mildenhall
Newmarket
Bury St Edmunds
Sandy
Kempston
Biggleswade
Haverhill
Clare


links_layer5_premises
links_layer4_distributions
links_layer3_cabinets
assets_layer5_premises
assets_layer4_distributions
assets_layer3_cabinets
assets_layer2_exchanges
links_layer5_premises
OpenStreetMap
Jesus Green
Midsummer Common
Jesus College (University of Cambridge)
Christ's College (University of Cambridge)
Christ's Pieces
Trinity College (University of Cambridge)
King's College (University of Cambridge)
Fisher Square
Emmanuel College (University of Cambridge)
Downing College (University of Cambridge)
Parker's Piece
Fenner's Cricket Ground
Mill Road Cemetery
The Grafton
Cambridge Retail Park
Brickyard Industrial Estate
Belfast Yard
Coldhams Lane
Romsey Recreation Ground
Coe Fen
Sheep's Green
Victoria Avenue
River Cam
A1303
A1134
A603
A307

Method: Objects



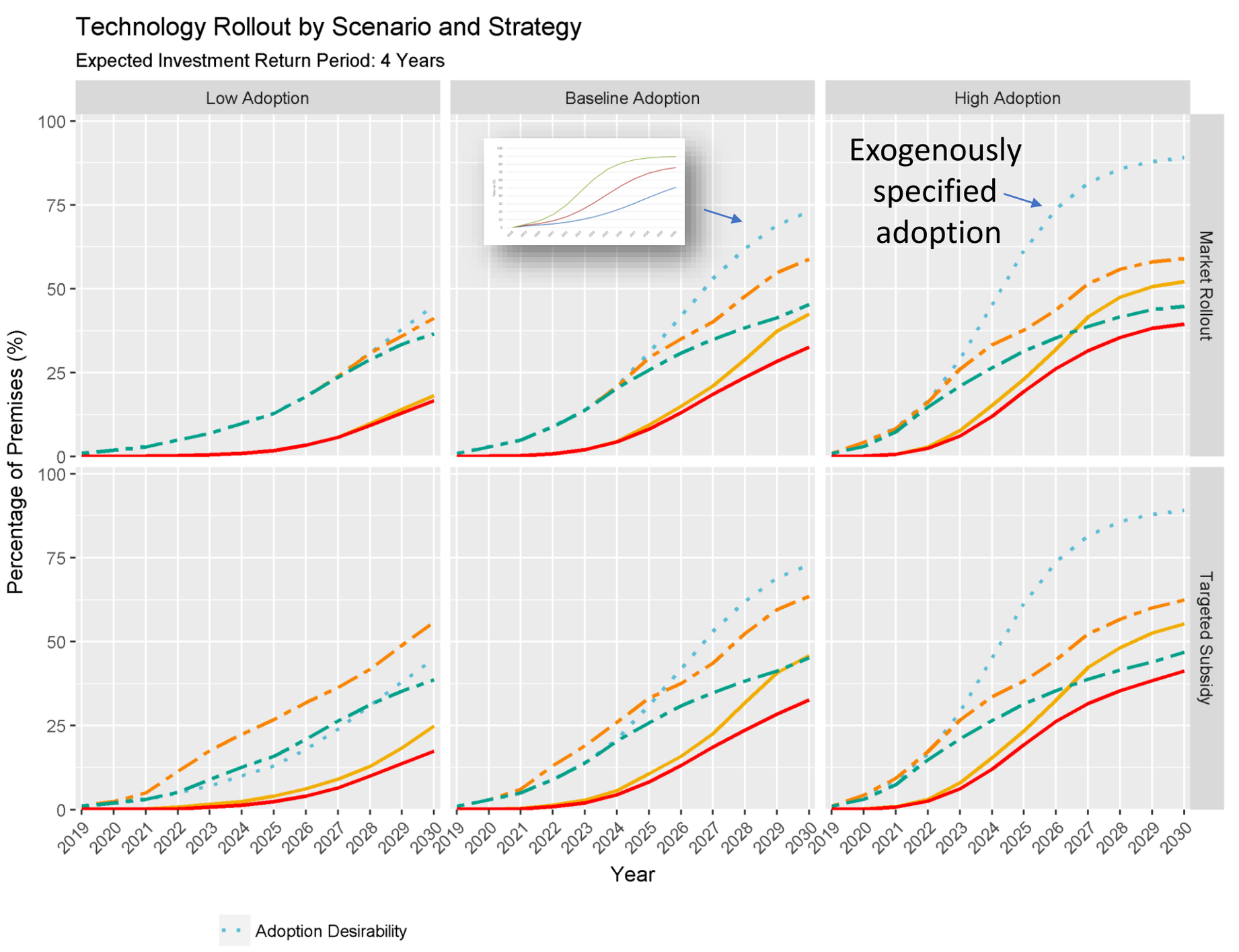
Method: FTTC, FTTdp and FTTP

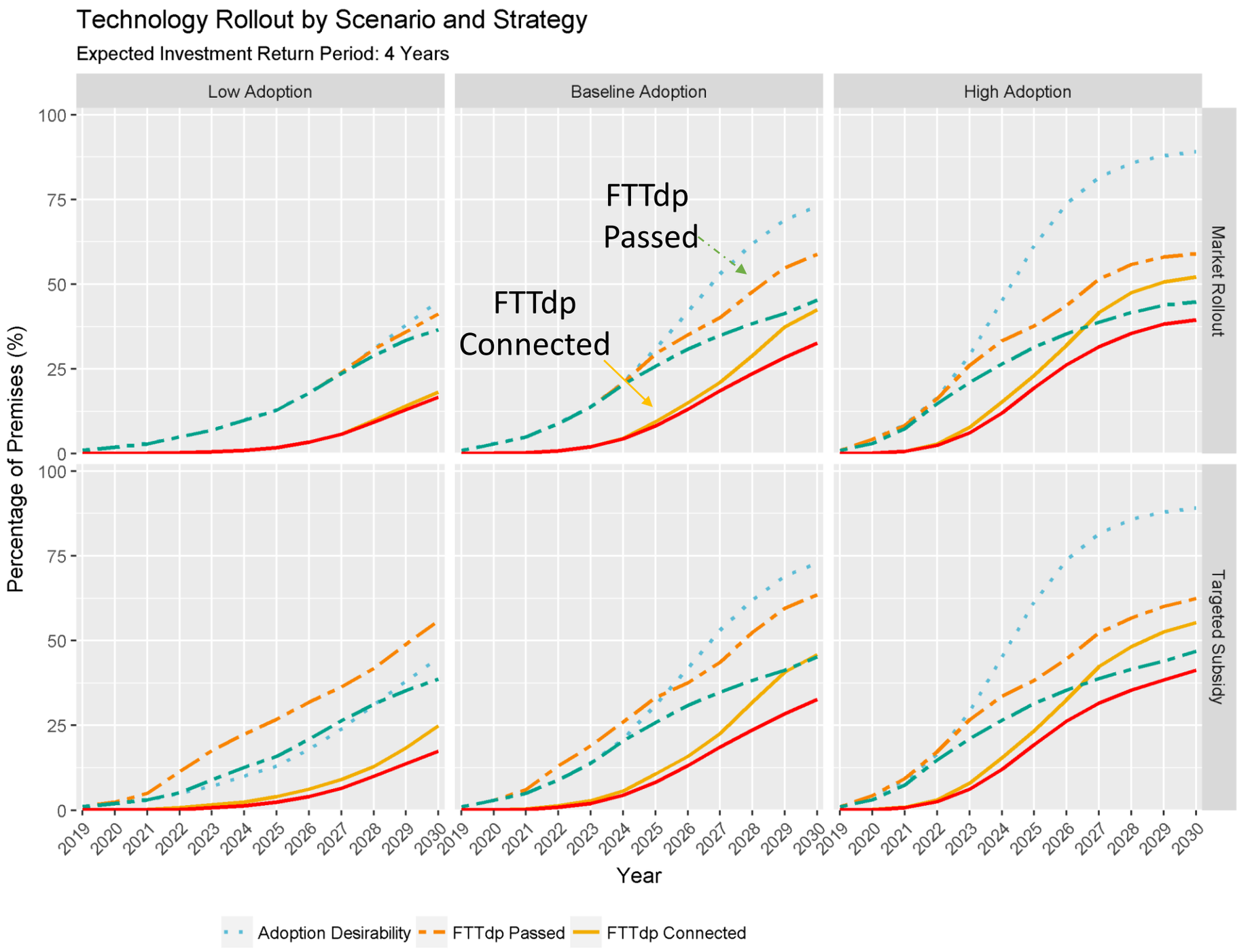


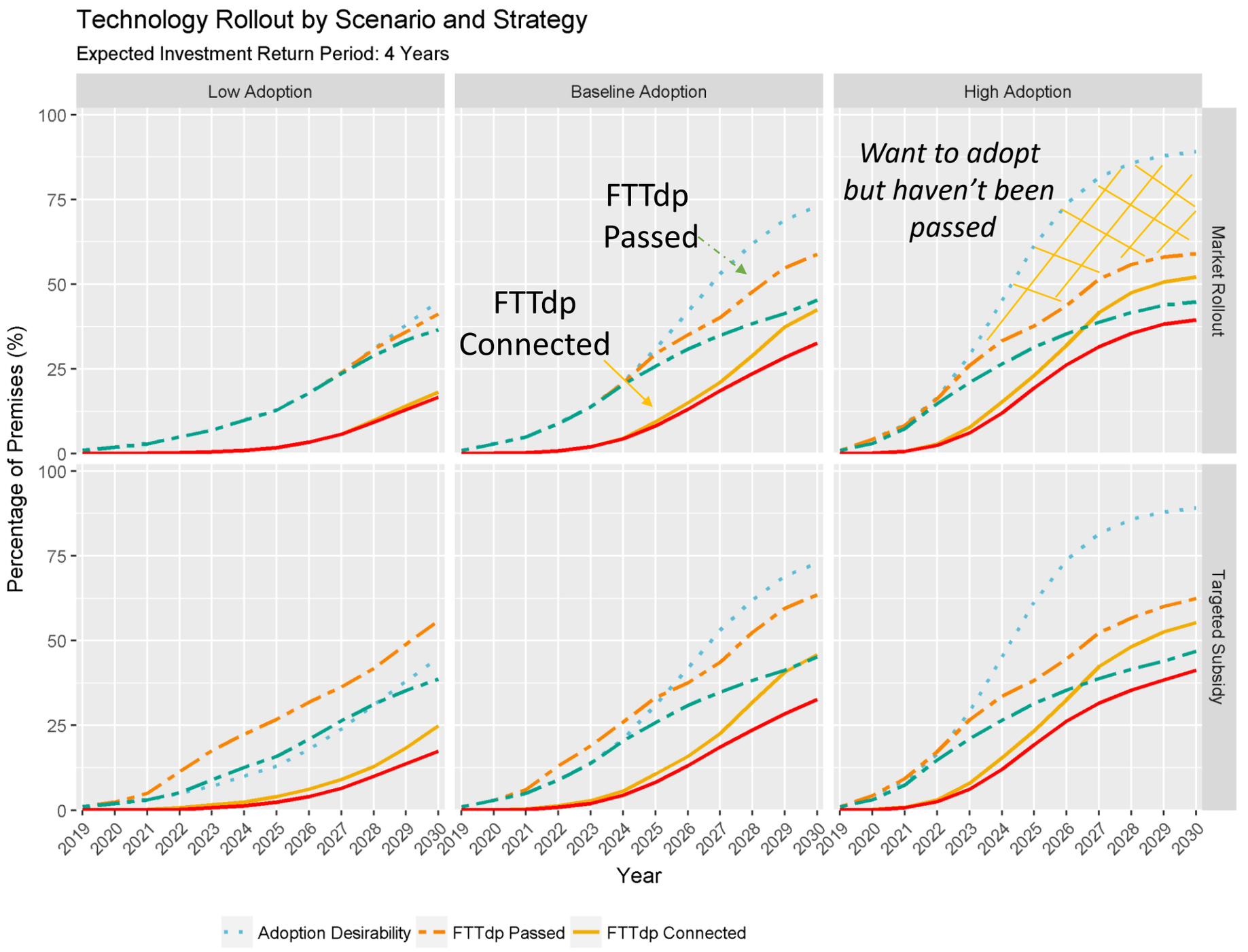
(Tactis and Prism, 2018 for HM Treasury)

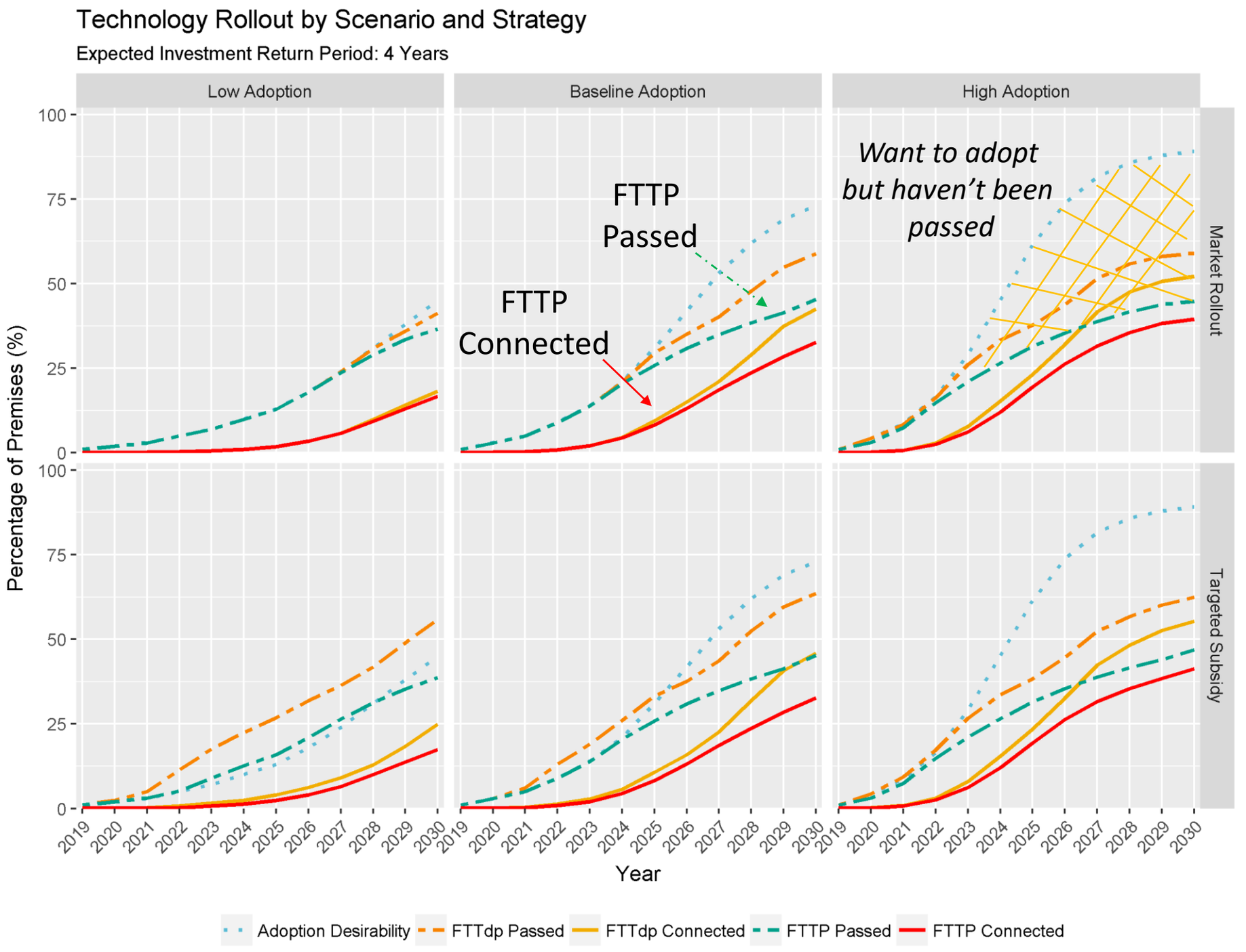
(All capex costs taken from Tactis and Prism, 2018 for HM Treasury)

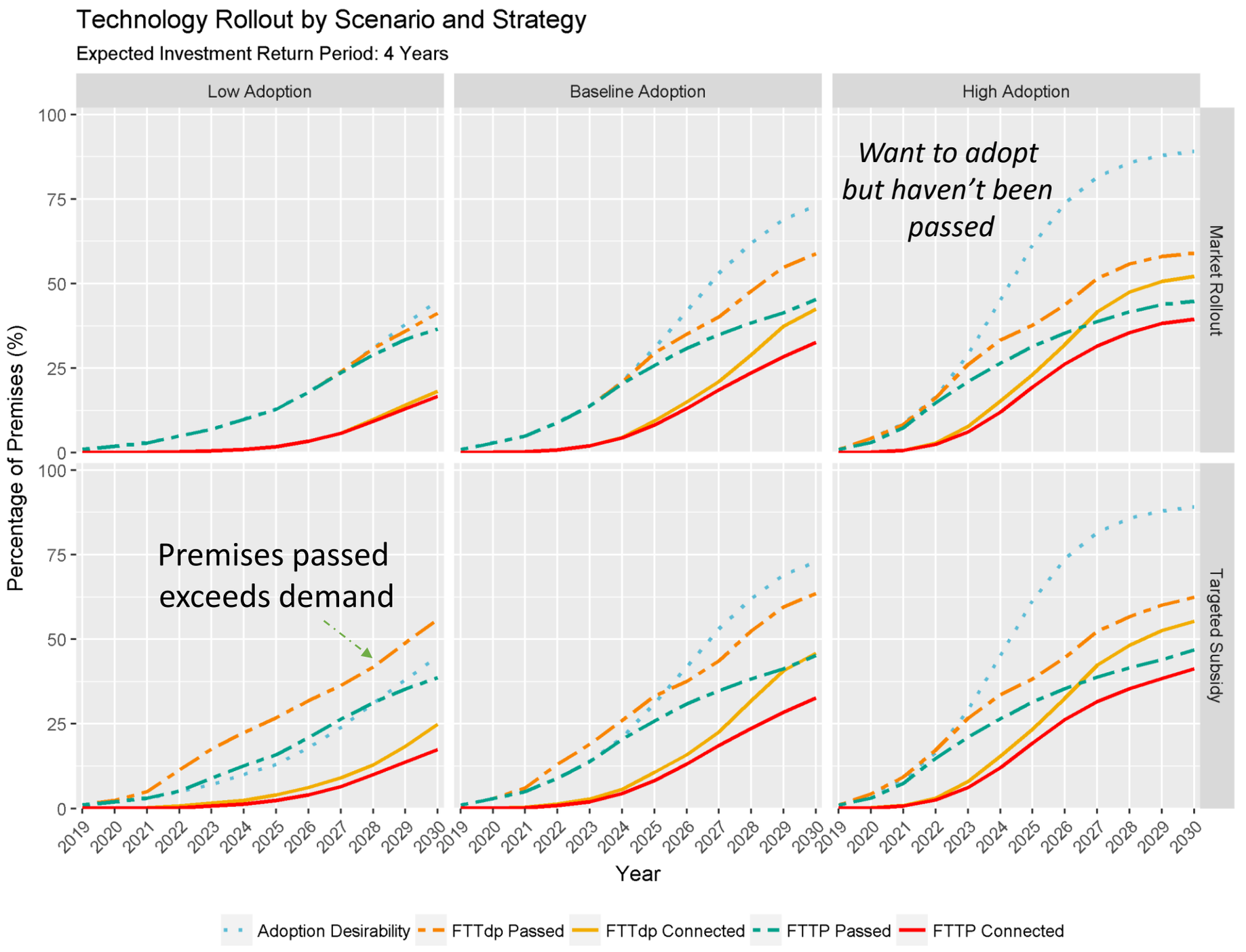
Asset	Costs
Fibre per metre	£10
Optical Connection Point	£45
G.Fast distribution point	£200
FTTP Customer Premises Equipment	£74
FTTdp Customer Premises Equipment	£37


Technology Rollout by Scenario and Strategy
Expected Investment Return Period: 4 Years
Low Adoption
Baseline Adoption
High Adoption
Market Rollout
Targeted Subsidy
Exogenously specified adoption
Percentage of Premises (%)
100
75
50
25
0
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Year
Adoption Desirability

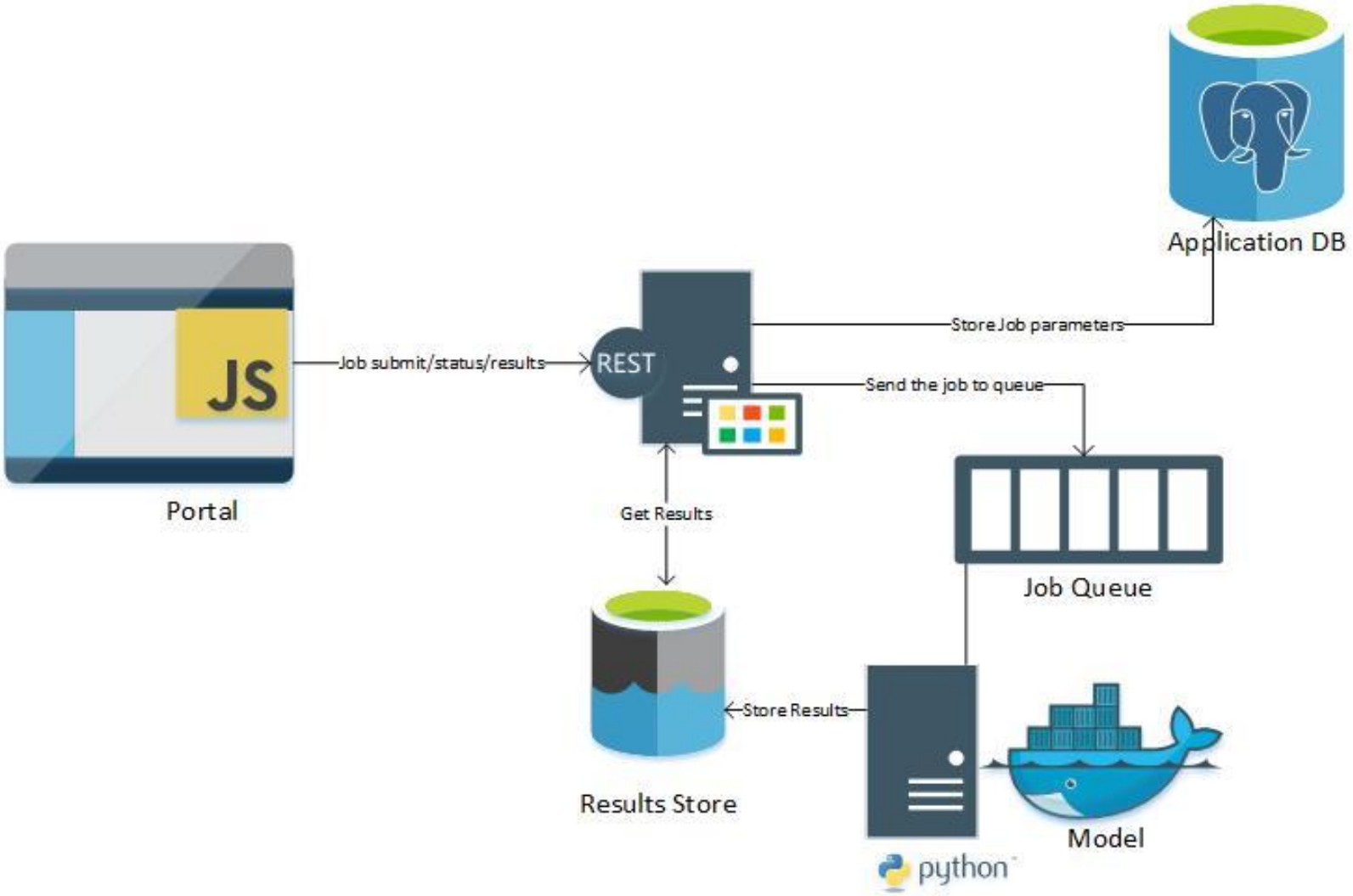

Technology Rollout by Scenario and Strategy
Expected Investment Return Period: 4 Years
Low Adoption
Baseline Adoption
High Adoption
Market Rollout
Targeted Subsidy
FTTdp Passed
FTTdp Connected
Percentage of Premises (%)
Year
Adoption Desirability
FTTdp Passed
FTTdp Connected

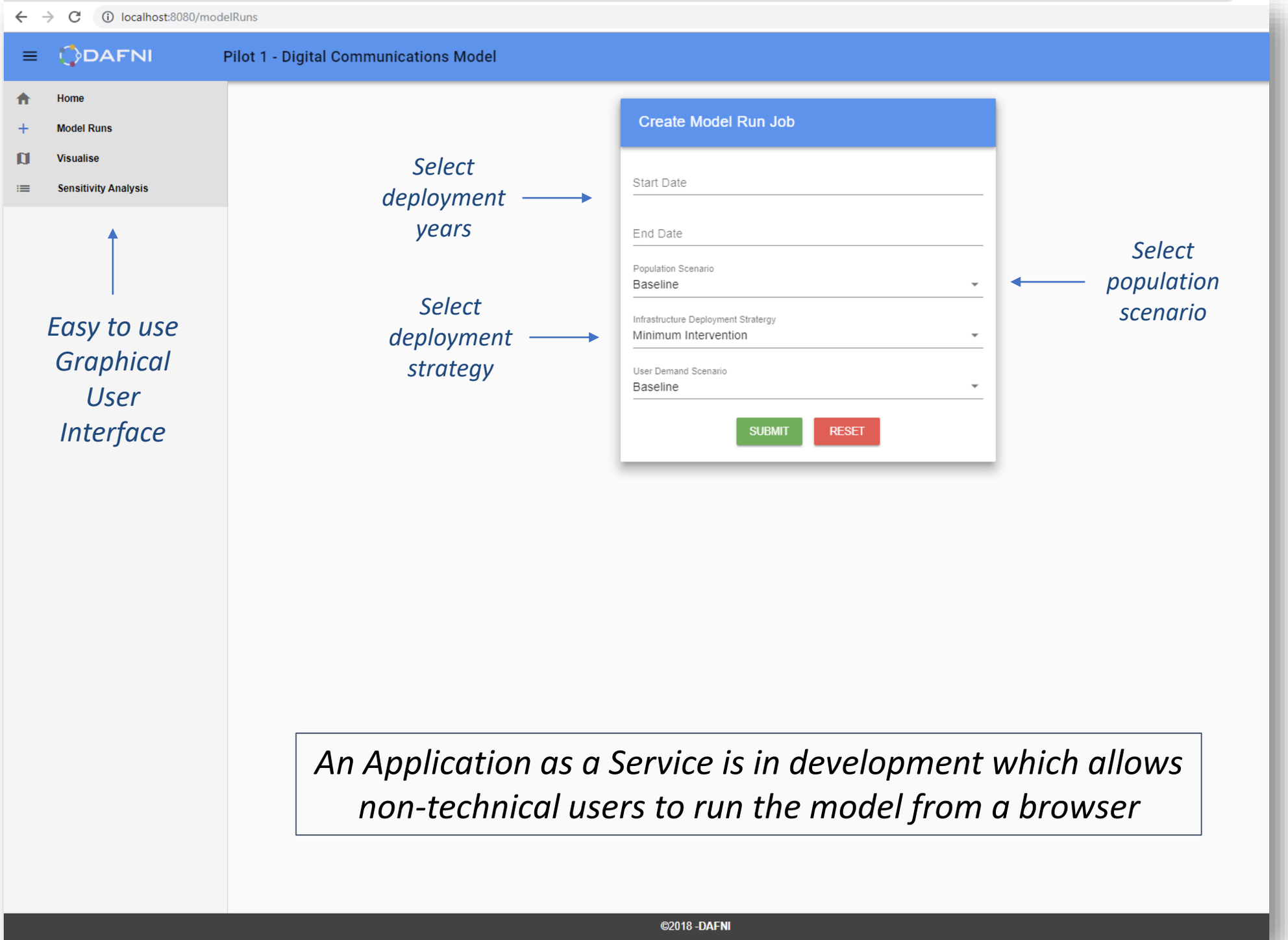

Technology Rollout by Scenario and Strategy
Expected Investment Return Period: 4 Years
Low Adoption
Baseline Adoption
High Adoption
Market Rollout
Targeted Subsidy
Percentage of Premises (%)
100
75
50
25
0
FTTdp Passed
FTTdp Connected
Want to adopt but haven't been passed
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Year
Adoption Desirability
FTTdp Passed
FTTdp Connected

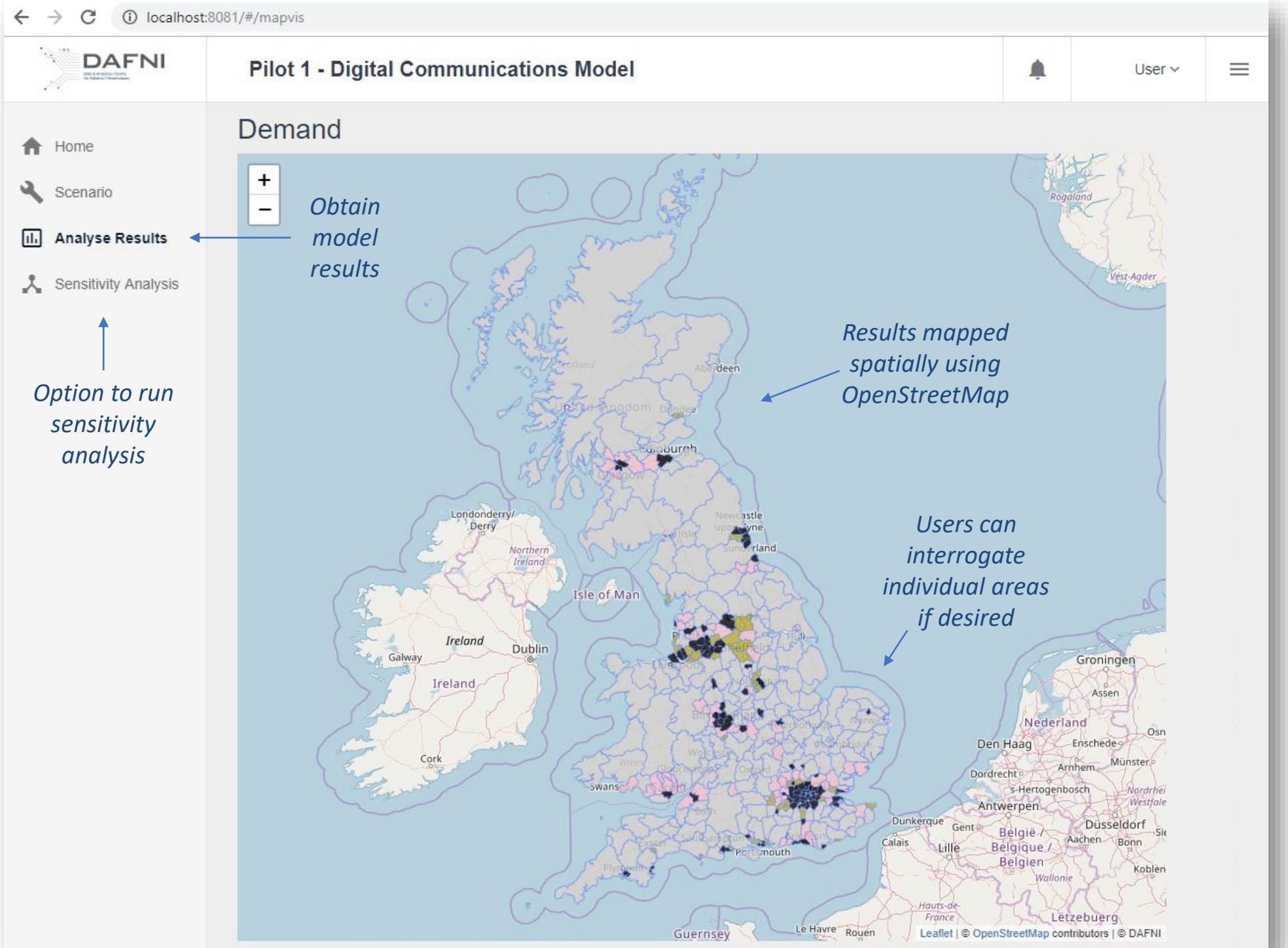

Technology Rollout by Scenario and Strategy
Expected Investment Return Period: 4 Years
Low Adoption
Baseline Adoption
High Adoption
Market Rollout
Targeted Subsidy
Percentage of Premises (%)
100
75
50
25
0
FTTP Passed
FTTP Connected
Want to adopt but haven't been passed
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Year
Adoption Desirability
FTTdp Passed
FTTdp Connected
FTTP Passed
FTTP Connected


Technology Rollout by Scenario and Strategy
Expected Investment Return Period: 4 Years
Low Adoption
Baseline Adoption
High Adoption
Market Rollout
Targeted Subsidy
Want to adopt but haven't been passed
Premises passed exceeds demand
Percentage of Premises (%)
Year
Adoption Desirability
FTTdp Passed
FTTdp Connected
FTTP Passed
FTTP Connected

Software Architecture




localhost:8080/modelRuns
DAFNI
Pilot 1 - Digital Communications Model
Home
Model Runs
Visualise
Sensitivity Analysis
Easy to use Graphical User Interface
Select deployment years
Select deployment strategy
Create Model Run Job
Start Date
End Date
Population Scenario
Baseline
Infrastructure Deployment Stratergy
Minimum Intervention
User Demand Scenario
Baseline
SUBMIT
RESET
Select population scenario
An Application as a Service is in development which allows non-technical users to run the model from a browser
©2018 -DAFNI


localhost:8081/#/mapvis
DAFNI
Pilot 1 - Digital Communications Model
User
Home
Scenario
Analyse Results
Sensitivity Analysis
Demand
Obtain model results
Option to run sensitivity analysis
Results mapped spatially using OpenStreetMap
Users can interrogate individual areas if desired
Rogaland
Vest-Agder
Aberdeen
Dundee
Edinburgh
Londonderry/ Derry
Northern Ireland
Isle of Man
Ireland
Galway
Dublin
Cork
Swansea
Portsmouth
Guernsey
Le Havre
Rouen
Groningen
Assen
Nederland
Den Haag
Enschede
Arnhem
Münster
Dordrecht
s-Hertogenbosch
Antwerpen
Dunkerque
Gent
Calais
Lille
België / Belgique / Belgien
Wallonie
Aachen
Bonn
Düsseldorf
Koblenz
Hauts-de-France
Letzebuerg
Leaflet | © OpenStreetMap contributors | © DAFNI

Codebase

README.md

The Cambridge Communications Assessment Model

docs latest | build passing | coverage 25%

(click on the 'docs' button to get directed to the full model documentation)

The Cambridge Communications Assessment Model currently focuses on the mobile sector to provide analytics for decision-makers on (i) capacity-demand and (ii) risk, vulnerability and resilience. The fixed, wireless and satellite sectors are currently under development.

Setup and configuration

All code is written in Python (Python>=3.5), avoiding external dependencies.

A word from our sponsors

The Cambridge Communications Assessment Model was written and developed at the Judge Business School, University of Cambridge and at the Environmental Change Institute, University of Oxford within the EPSRC-sponsored MISTRAL programme, as part of the Infrastructure Transition Research Consortium.

Install

For development purposes:

Run this command once per machine:

www.github.com/nismod/digital_comms

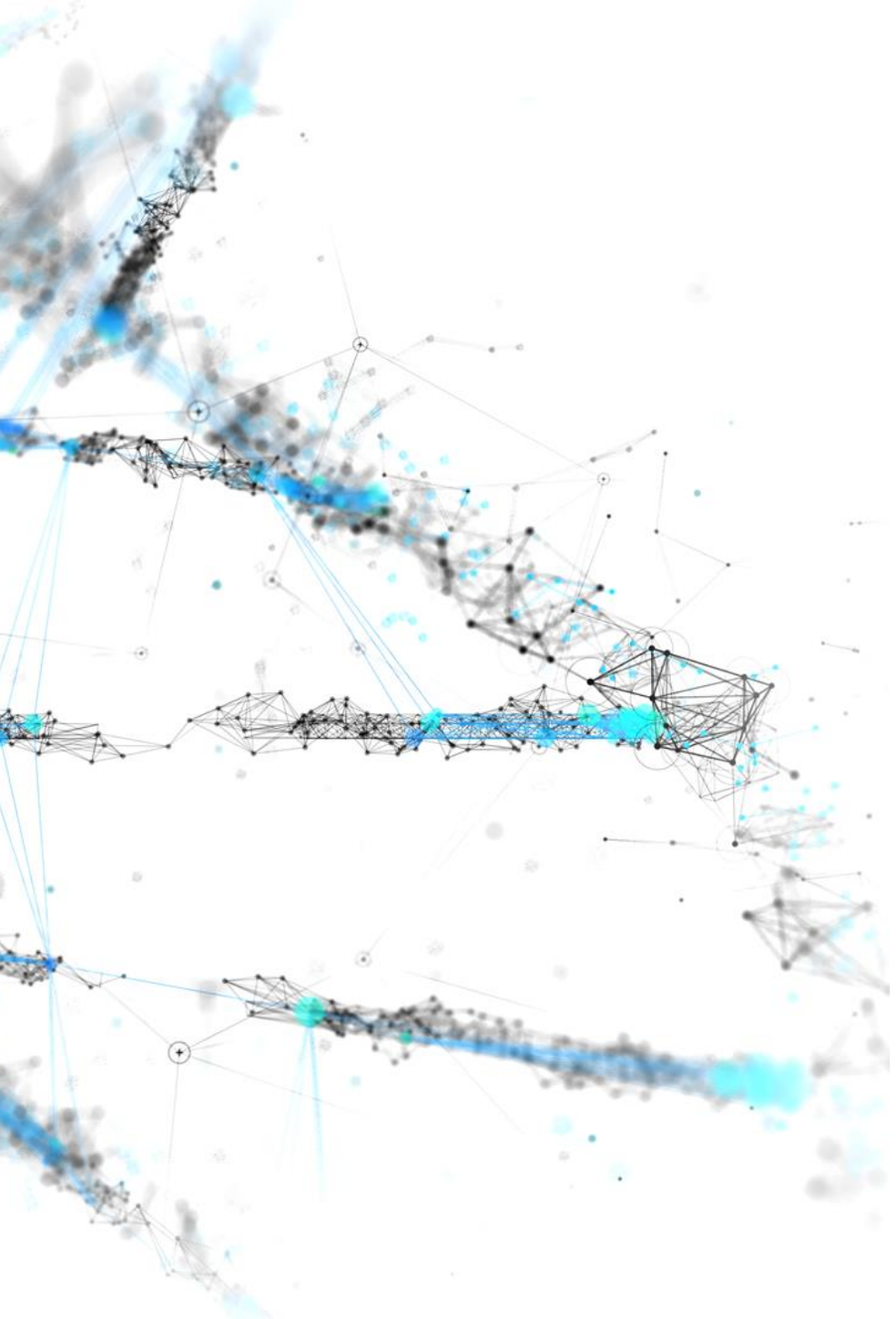
***How** may the Digital Twin concept enhance our existing approach to testing policy options?*

What *characteristics does a Digital Twin require?*

Why *may a Digital Twin help support better decisions?*

Contribution:

Development of an ***open-source*** *fixed broadband assessment framework*



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