ITU Regional Seminar for CIS and Europe

Development of modern radiocommunication ecosystems

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St. Petersburg, Russian Federation

Economic Aspects of Redeployment in 3400 – 3800 MHz Spectrum Band

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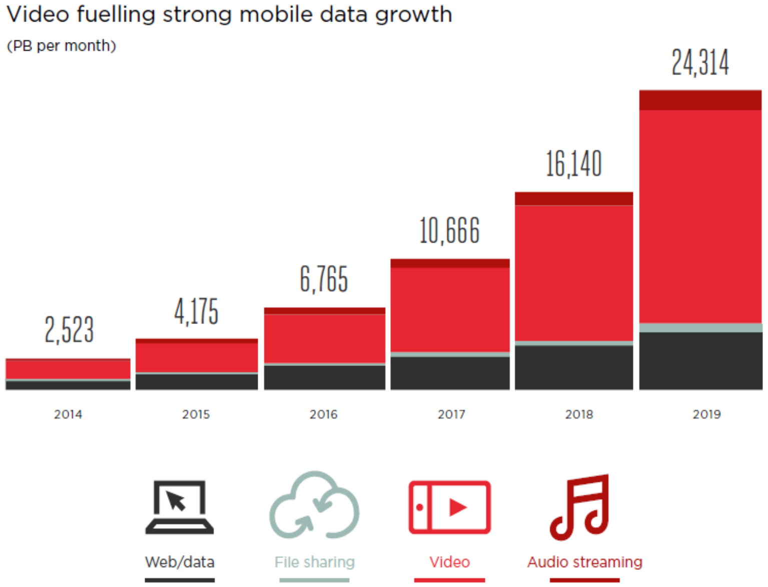
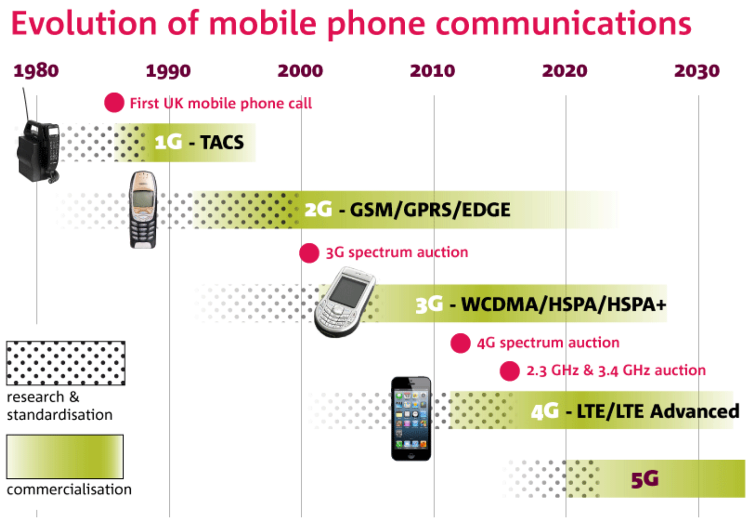
The Footings of Spectrum Re-allocation

Towards the economy of gigabytes…



Source: GSMA

Turnover of radio technologies…



Source: Http://tutorvoice.com/index.php/2015/10/11/generations-of-wireless-communication-technology/

Revolving spectrum allocations…

WRC-07 candidate bands	WRC-07 identified bands	WRC-15 Candidate bands	WRC-15 Identified bands
410 – 430 MHz	450 – 470 MHz	470 – 698 MHz	694 – 790 MHz
450 – 470 MHz	698 - 806 MHz	1350 – 1400 MHz	1427 – 1518 MHz
470 – 862 MHz	790 – 862 MHz	1427 – 1452 MHz	3300 – 3700 MHz
2300 – 2400 MHz	2300 – 2400 MHz	1452 – 1492 MHz	4800 – 4990 MHz
2700 – 2900 MHz	3400 – 3600 MHz	1492 – 1518 MHz	
3400 – 3600 MHz		1518 – 1525 MHz	
3600 – 3800 MHz		1695 – 1710 MHz	
3800 – 4200 MHz		2700 – 2900 MHz	
4400 – 4990 MHz		3300 – 3400 MHz	
		3600 – 3700 MHz	
		3700 – 3800 MHz	
		3800 – 4200 MHz	
		4400 – 4500 MHz	
		4500 – 4800MHz	
		4800 – 4990 MHz	
		5350 – 5470 MHz	
		5725 – 5850 MHz	
		5925 – 6425 MHz	

Growing demand for data is satisfied by evolving radio technologies with greater geographic reach and capacity, advanced handsets with increased processing power, larger screens, ubiquitous social media, messaging, video streaming. Data traffic is growing exponentially 60% annually.

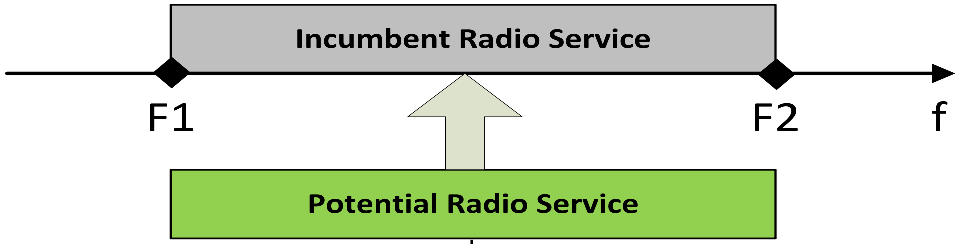
The pace of change in radio technologies is speeding up. From ten years life cycle of new generation in the past, now turnover is increasing. The advent of 4G LTE happened six/seven years from the mass commercial adoption of 3G. 5G is estimated to happen four/five years from adoption of 4G.

ITU is in the pervasive rush of seeking for new allocations for emerging radio technologies.

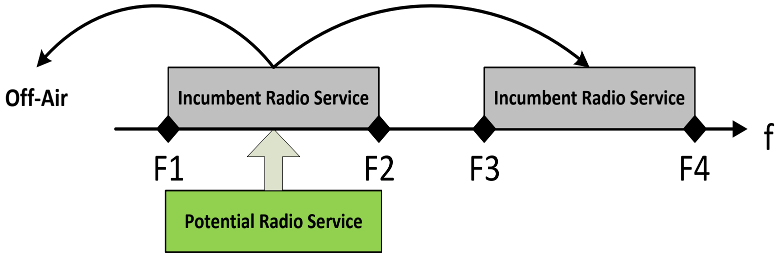
Effectively each WRC adopts a host of new spectrum bands for developing and emerging advanced radio technologies.

Methods to Achieve Spectrum Turnover

Target Setting

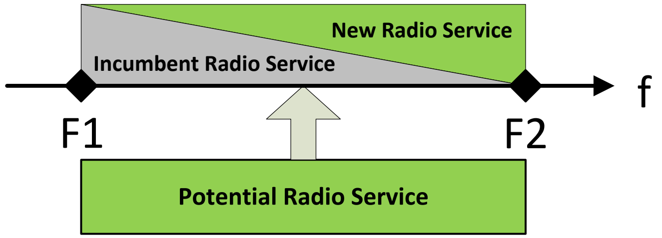


Spectrum Re-allocation



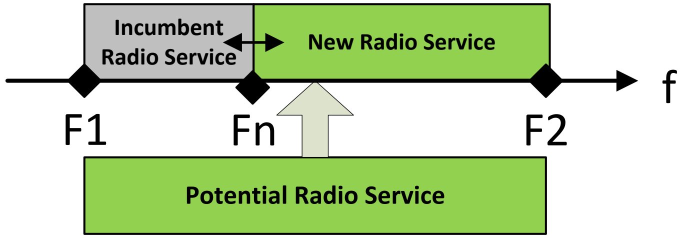
- ❑ Determination of alternative band for incumbent service.
- ❑ Determination of alternative off-air technology.
- ❑ Compensation for redeployment.
- ❑ Re-allocation fund.

Spectrum Sharing



- ❑ Is sharing technically feasible?
- ❑ What are the technical constraints of sharing both for incumbent and potential radio services?
- ❑ For how long both services are able to coexist in the same band?

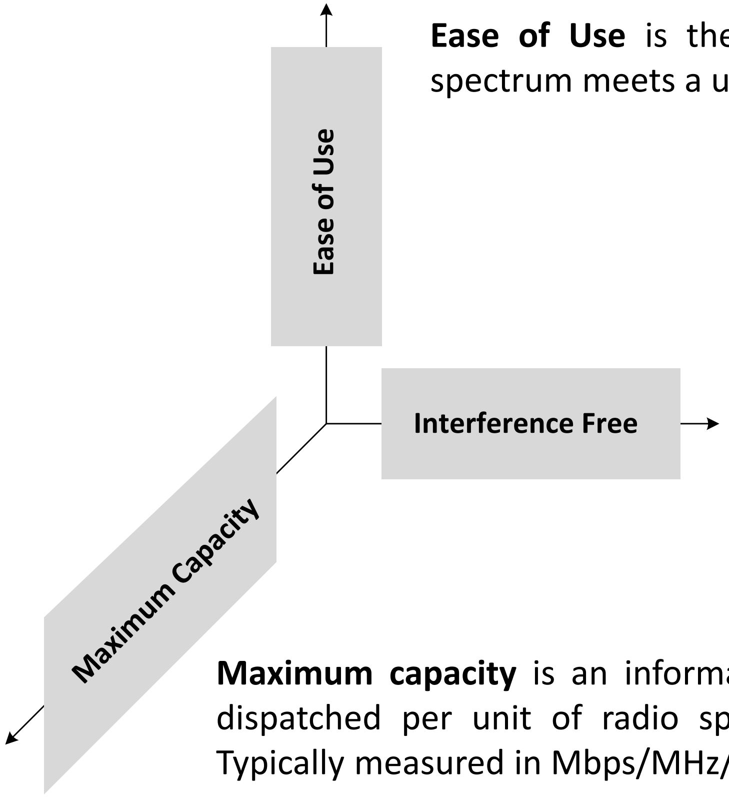
Spectrum Band Subdivision



- ❑ Assessment of spectrum efficiency of the incumbent service.
- ❑ Inventory and optimization of frequency plan for incumbent service.
- ❑ Assessment of total spectrum value for both incumbent and potential services.
- ❑ Finding optimal proportion of sub-bands.

Two Components of Spectrum Efficiency

Technical Efficiency of Spectrum

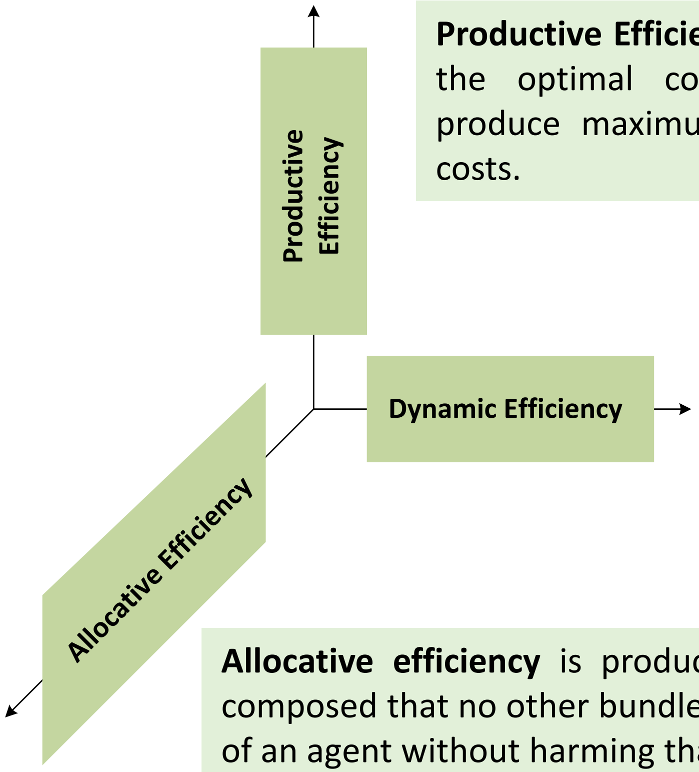


Ease of Use is the extent to which the use of spectrum meets a user's specific needs.

Interference free is an avoidance of critical degradation of quality of operation due to mutual influence of different emissions.

Maximum capacity is an information throughput that can be dispatched per unit of radio spectrum per unit of location. Typically measured in Mbps/MHz/ km^2

Economic Efficiency of Spectrum



Productive Efficiency is supply of services with the optimal combination of resources to produce maximum output for the minimum costs.

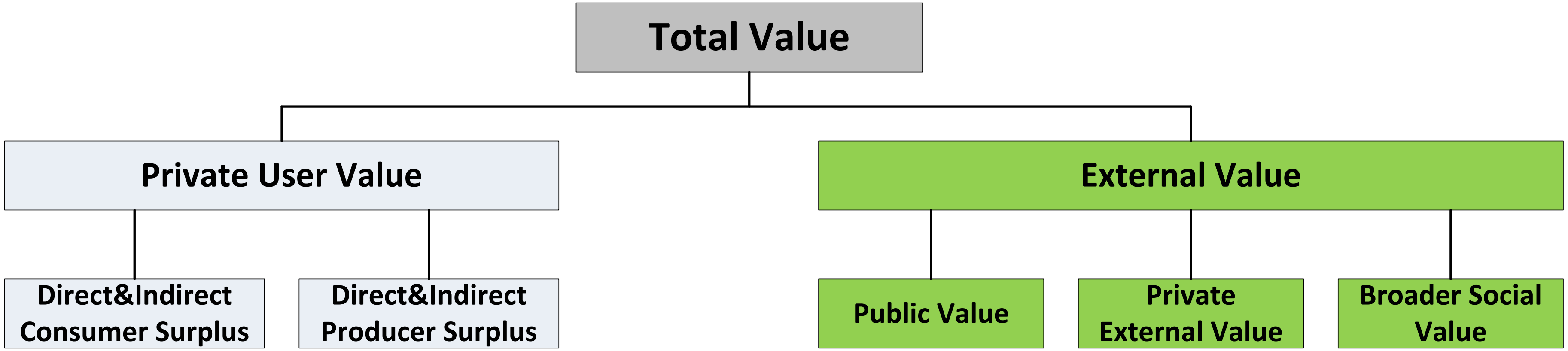
Dynamic efficiency is using the resource in a way enabling long-term productivity improvements through innovation and R&D.

Allocative efficiency is producing a bundle of services so composed that no other bundle could improve the well-being of an agent without harming that of another agent. Allocative efficiency relies on the Pareto criteria, that is, being able (or not) to improve the well-being of one economic agent without restricting that of another agent.

Maximizing technical efficiency does not always maximizes total benefits from spectrum for the society

Pivotal Components of Total Value of Spectrum for Society

The value of spectrum for society is defined by benefits for consumers, producers and citizens from spectrum-utilizing services



Private User Value is the benefit to individuals from consumption of the services, less the costs of producing the services.

Private User Value is equal to the sum of consumer and producer surplus.

Direct benefits are benefits for service consumers and producers generated from the direct consumption and provision of radio services.

Indirect benefits are generated due to unintended effects of direct service on other product markets thus resulting in further indirect increase of producers and customers surplus.

External value is the additional benefits to society not reflected in the value of the service to consumers/producers.

Public value is the benefit that society derives from consuming public goods based on "non-excludability" and "non-rivalry" (such as defense).

Private External Value is the net private value to individuals that do not use services but are affected by positive or negative externalities.

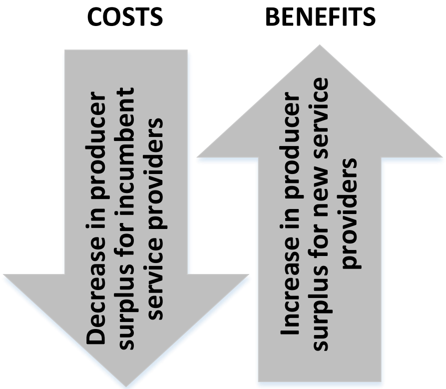
Broader Social Value is the benefit for citizens from the contribution of spectrum to social goods incl. social capital, political freedoms, national culture, equality etc. irrespective of incomes.

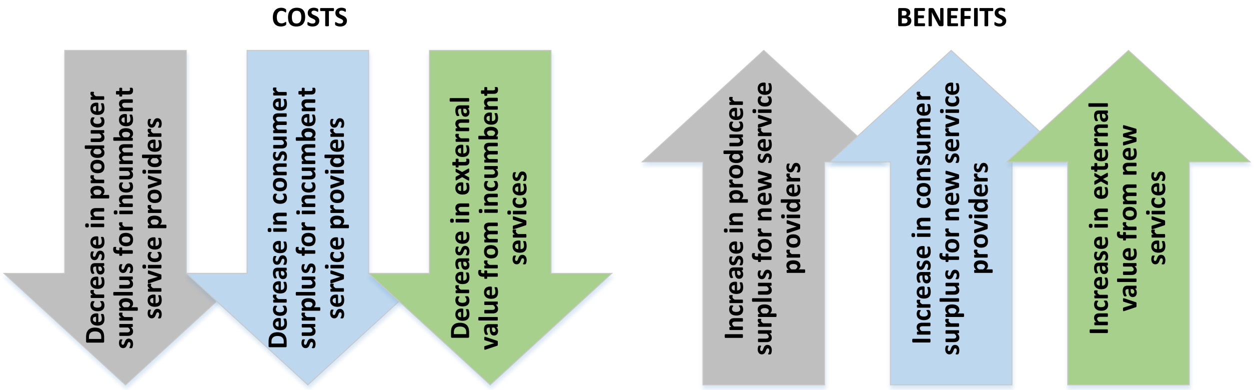
Can be validly expressed in the monetary terms

Non-market valuation methods can be applied

Constant versus Variable Output Cases

Constant Output Case	Variable Output Case
The provider of the existing service is able to fully mitigate the impact of the change in spectrum use through the combination of different spectrum, additional network investment, and/or increased use of other inputs and methods of supply, assuming an increased cost of supply. The new service uses the additional spectrum to provide the same output at lower cost.	The change in spectrum use affects the output and cost of one or both services: the existing service may be unable to maintain its output, even after taking mitigation steps. It is possible, though unusual, that the reduction in spectrum means that the existing service can no longer be provided at all. The new service may be able to use the additional spectrum in order to increase or improve its output.





The variable output case is more complex, and will require an assessment of the incremental impact of the change of allocation on the producer and consumer values, and external value for both services.

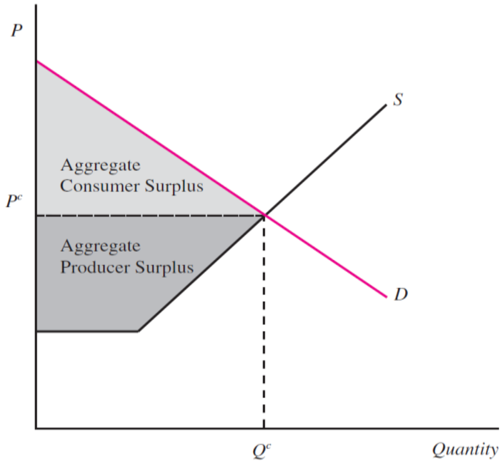
Source: Report to UK Department for Culture, Media and Sport "Incorporating Social Value into Spectrum Allocations Decisions", November 2015

Spectrum Redeployment. Estimation of Total Value Components

Total Value

- **Private User Value**
- **External Value**

Can be validly expressed in the monetary terms



Total Surplus in a Competitive Market
Source: Church and Ware (2000)

Market price methods estimate private value that individuals derive from spectrum services/goods based on their purchase decisions in the market place.

Apply to goods/services in order to provide estimates of willingness to pay (**WTP**) based on market prices, as though, on relationship between demand and price.

Auction is the best way to capture Private User Value in making decision on potential allocation.

Economic (non-market) valuation methods

Technique	Description
Revealed Preference	Involves identification of complementary market good whose price captures the impact of non-market good.
Stated Preference	Relies on asking hypothetical questions via a survey (contingent valuation) or choice experiment (conjoint measurement), to see how people respond to a range of choices and to establish the extent of WTP for a particular benefit.
Deliberate Research	Aims to involve the public in decision-making. It enables a limited number of participants to find out more about a topic, consider relevant evidence, discuss this evidence and present their views on the topic.
Subjective Wellbeing	Uses subjective wellbeing data to attach monetary values to non-market goods. It relies on the availability of time series data that allows analyst to identify the impact of potential change in spectrum services on wellbeing.

Source: Report to UK Department for Culture, Media and Sport “Incorporating Social Value into Spectrum Allocations Decisions”, November 2015

If the costs and benefits of External Value are not taken into account, there is a risk to worsen results of redeployment.

Redeployment Stakeholders in 3400 – 3800 MHz Band

Fixed Wireless Broadband

Fixed Satellite Service Earth Stations

Point-to-Point Links

C-band is Heavily Loaded by a Number of Traditional Applications and Services

Redeployment Benefits

1. Additional revenues/lowering of costs for producers (producer surplus) and reduction of price/increased quality of new services for customers (consumer surplus) are major factors of redeployment.

2. The value placed by potential user on new spectrum is a proxy for economic benefits of redeployment.

Value of 3.6 GHz from potential MNO ($/MHz/pop)

Updated average prices per MHz per capita for a 15-year Irish licence

	All	European	Since 2010	European since 2010
All	€0.0247	€0.0194	€0.0484	€0.0380
3.6GHz	€0.0152	€0.0084	€0.0116	€0.0116
2.6GHz	€0.0412	€0.0372	€0.0762	€0.0607
2.3GHz	€0.0287	€0.0086	€0.1146	NA

MNO's valuations could be obtained in public consultation process. High demand of 3.6 GHz due to excellent characteristics (trade-off between beamforming, massive MIMO and coverage, in-building penetration).

Comparisons with recent re-issue prices for non-5G licences spectrum with relatively similar characteristics (e.g. FWA in 2300 MHz).

Comparisons with recent auction prices for 5G spectrum in 3600 MHz and other 5G bands (e.g. 700 MHz).

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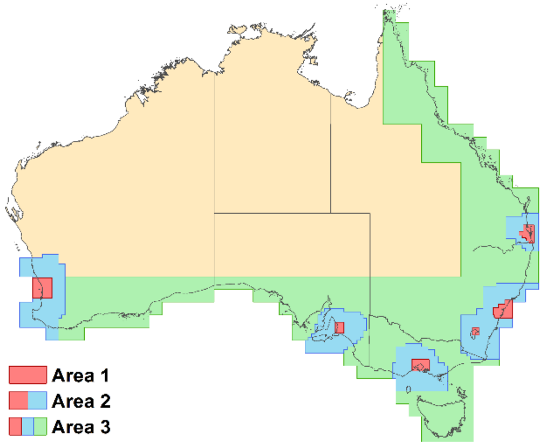
Geographic Area (population)



Geographic area options for licencing/redeployment are crucial as influencing population covered, number of incumbents to be displaced and bandwidth available from current users.

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Bandwidth Available (MHz)

NR Operating Band	Uplink Operating Band	Downlink Operating Band	Duplex Mode
n77	3300 – 4200 MHz	3300 – 4200 MHz	TDD
n78	3300 – 3800 MHz	3300 – 3800 MHz	TDD

NR band / SCS / BS channel bandwidth														
NR Band	SCS kHz	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	70 MHz	80 MHz	90 MHz	100 MHz
n77	15		Yes		Yes		Yes	Yes	Yes					
	30		Yes		Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	60		Yes		Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
n78	15		Yes		Yes		Yes	Yes	Yes					
	30		Yes		Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	60		Yes		Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Ideally – 100 MHz per 5G MNO. Setting aside a portion of the 3.6 GHz band for remaining services or protection of incumbents from interference are decreasing essentially the valuations of redeployments benefits.

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Total Willingness to Pay Reflects the Economic Benefits of Spectrum Redeployment

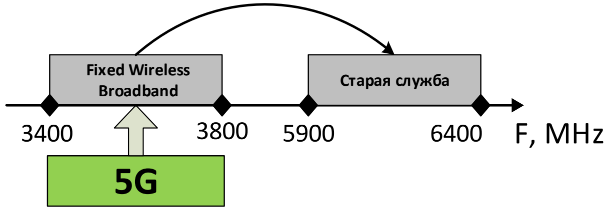
Source: Report of ACMA "Future use of 3.6 GHz band. Highest value use assessment – Quantitative analysis". June 2017

Incremental Costs of Redeployment for Fixed Wireless Broadband Licences

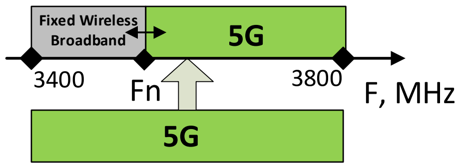
Fixed Wireless Broadband (FWB) Incumbents might represent both constant and variable output cases

Constant Output Case

Alternative Band

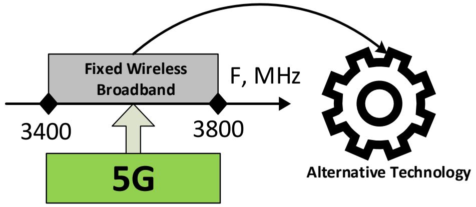


Sub-band Set Aside

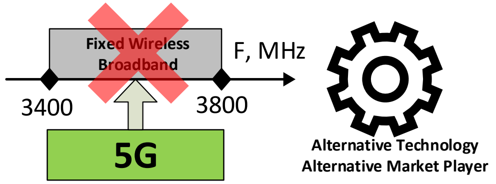


Variable Output Case

Alternative Technologies



Incumbent Services Terminated



	Alternative Band	Sub-band Set Aside	Alternative Technologies	Incumbent Services Terminated
Producer Surplus	The costs of shifting FWB operators to new spectrum bands may result in a decline in producer surplus, which translates into a decline in the net economic welfare.	Incremental costs of FWB operators would be significantly reduced and producer surplus secured in case of the availability of re-tuning scenarios.	Transition to alternative technologies may result in reducing producer surplus due to changing business cases, additional investment, change of input resources etc.	Incumbent producer surplus falls down to zero. Alternative producer surplus increases. Averaged total economic welfare may be negative or positive.
Consumer Surplus	No change	No change	Users considering incumbent FWB as the only possible option for delivering services will suffer reduction of consumer surplus.	Users considering incumbent FWB as the only possible option for delivering services will suffer reduction of consumer surplus.
External Value	No change	No change	The impact on external (social) value is anticipated if alternative services are unable to substitute drop-down services.	The impact on external (social) value is anticipated if alternative services are unable to substitute drop-down services.

Incremental costs for constant output case could be easily estimated based on equipment prices and costs of its replacement/re-tuning.

Typically consumer surplus and external value changes are highly difficult to quantify, qualitative estimates are required

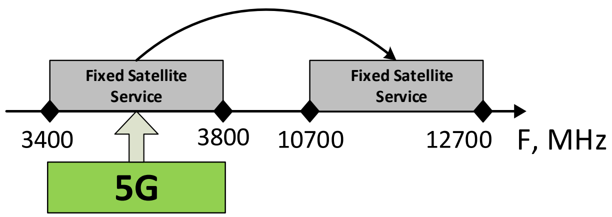
Incremental Cost of Redeployment for Incumbent FSS Earth Stations

The majority of incumbent FSS earth receive licences are considered to be constant output cases.

Frequency Relocation	Geographic Relocation

Frequency Relocation

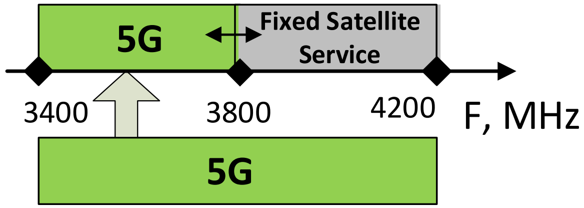
Alternative Band



It may be possible for FSS Earth Stations to relocate their services to a different band, including the adjacent 3800–4200 MHz band. It should be noted that it may not be a simple or practical option in many cases.

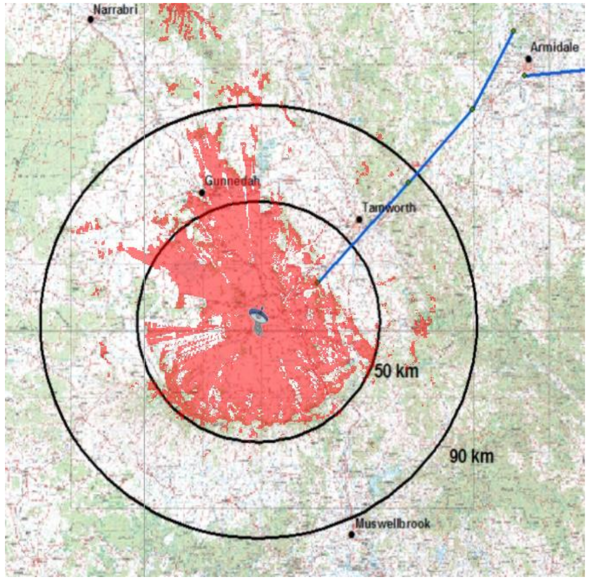
There are different factors defining the carrier frequency of a FSS Earth Station, which are not always easily controlled by the FSS operator.

Sub-band Set Aside



There may be limited opportunity to move FSS Earth Station to other portions of the band.

Geographic Relocation



There would be numerous costs involved in acquiring and constructing a new Earth Stations located in a regional or remote area. These costs include land acquisition, construction of building facilities, labour accommodation costs, power and fibre interconnection for the new facility.

Costs would be involved in either relocating existing C-band antennas and radio equipment from existing sites or investment in new equipment.

There may be additional costs involved in operating a new facility from a regional or remote location that would not be incurred with existing facilities.

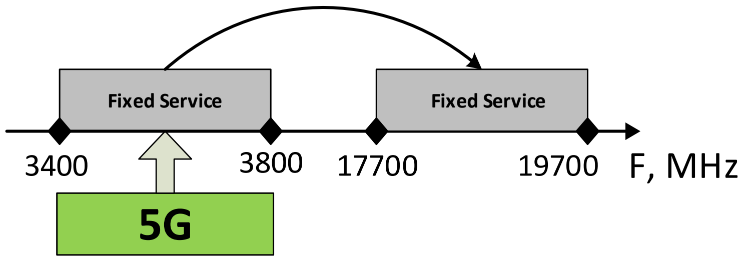
There is not expected to be any material decline in output due to frequency relocation or geographic relocation, which means the only effect on the net economic welfare is anticipated to be a decline in producer surplus related to relocation costs.

Source: Report of ACMA “Future use of 3.6 GHz band. Highest value use assessment – Quantitative analysis”. June 2017

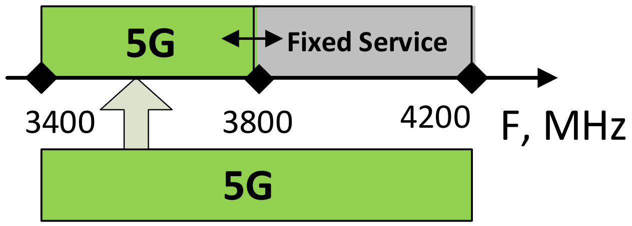
Incremental Costs of Redeployment for Incumbent Point-to-Point Licences

Point-to-point licensees have multiple options for frequency relocation. These applications will therefore all be considered constant output cases.

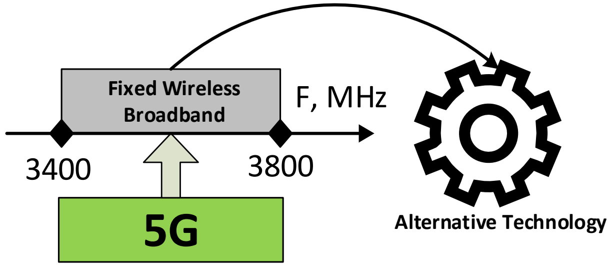
Relocation to Alternative Bands = Equipment Replacement



Sub-band Set Aside = Equipment Re-tuning



Substituting Technologies = Using Fiber Links



Regulators should estimate a ratio of point-to-point licences that are able to be replaced to those able to be re-tuned. This ratio will influence incremental costs and the associated reduction in producer surplus. Replacement costs are higher than re-tuning costs. Therefore, a higher proportion of licences that need to be replaced rather than re-tuned will result in much higher incremental costs

The producer surplus is likely to be decreased due to investments needed to deploy new or lease the existing fibre links

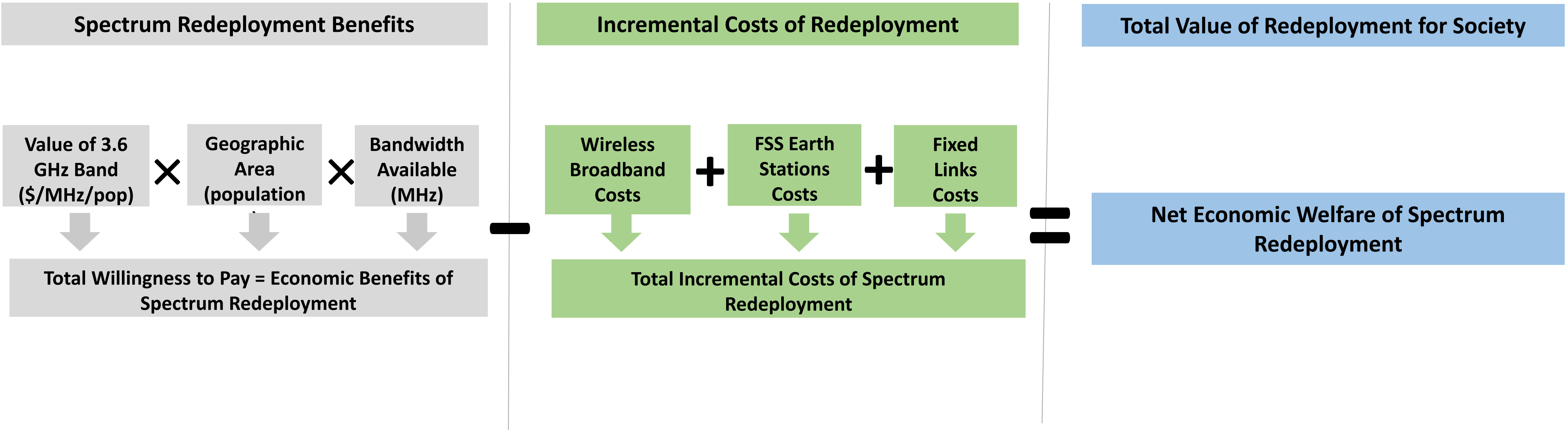
The incremental costs associated with relocating point-to-point licences will depend on how many licences require equipment replacement, as opposed to licences with equipment that can be re-tuned to another channel in the 3.8 GHz fixed link band.

Source: Report of ACMA "Future use of 3.6 GHz band. Highest value use assessment – Quantitative analysis". June 2017

Economic Welfare Impact of 3.6 GHz Band Redeployment

The net benefit of the 3.6 GHz band redeployment is the difference between the:

- **economic welfare benefits = total willingness to pay for the spectrum by potential users**
- **incremental costs of displacing incumbent licensees from the band**



There will be a net economic benefit for a society if the spectrum redeployment benefits of the band being available for 5G licensing is higher than the incremental costs of displacing incumbent licences. This will ultimately mean that the new use following redeployment would be the highest value use of the spectrum.

Source: Report of ACMA "Future use of 3.6 GHz band. Highest value use assessment – Quantitative analysis". June 2017

Conclusions

To conclude on whether the total value for society from usage of 3400 – 3800 MHz band by 5G is the preferred option, the spectrum redeployment benefits of 5G need to exceed the incremental costs of displacing incumbent users.

The assessment of redeployment benefits could be based on the valuations of 3400 – 3800 MHz spectrum by the potential operators. These valuations are true indicators of economic welfare increase that the spectrum can provide to providers primarily by lowering network deployment costs and/or providing new or improved services.

Constant output and variable output cases should be distinguished. In constant output cases there is no change in final output noting a reduction in producer surplus due to the costs accruing from providing service in alternative band or using alternative technology. Variable output cases assume a change in final output impacting producer surplus, consumer surplus and broader social benefits of spectrum. External spectrum value is complicated for quantitative analysis.

The initial quantitative assessments of 3400 – 3800 MHz band redeployment benefits and incremental costs are indicating that refarming of this band will have the positive economic welfare impact thus providing increase in total benefits of spectrum for the society.

Thank You