On the path to 6G

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5Is Executive Summary and Table of Contents

1 Intelligence

By 2030, 6G is expected to enable the **merging of physical and digital worlds**

2 Insight

6G targets superior characteristics for **new digital paradigms**

3 Innovation

Several countries launched national 6G programs to be a **designer, developer and/or adopter**

4 Interaction

There are **initiatives** that could be launched as a part of a 6G development program
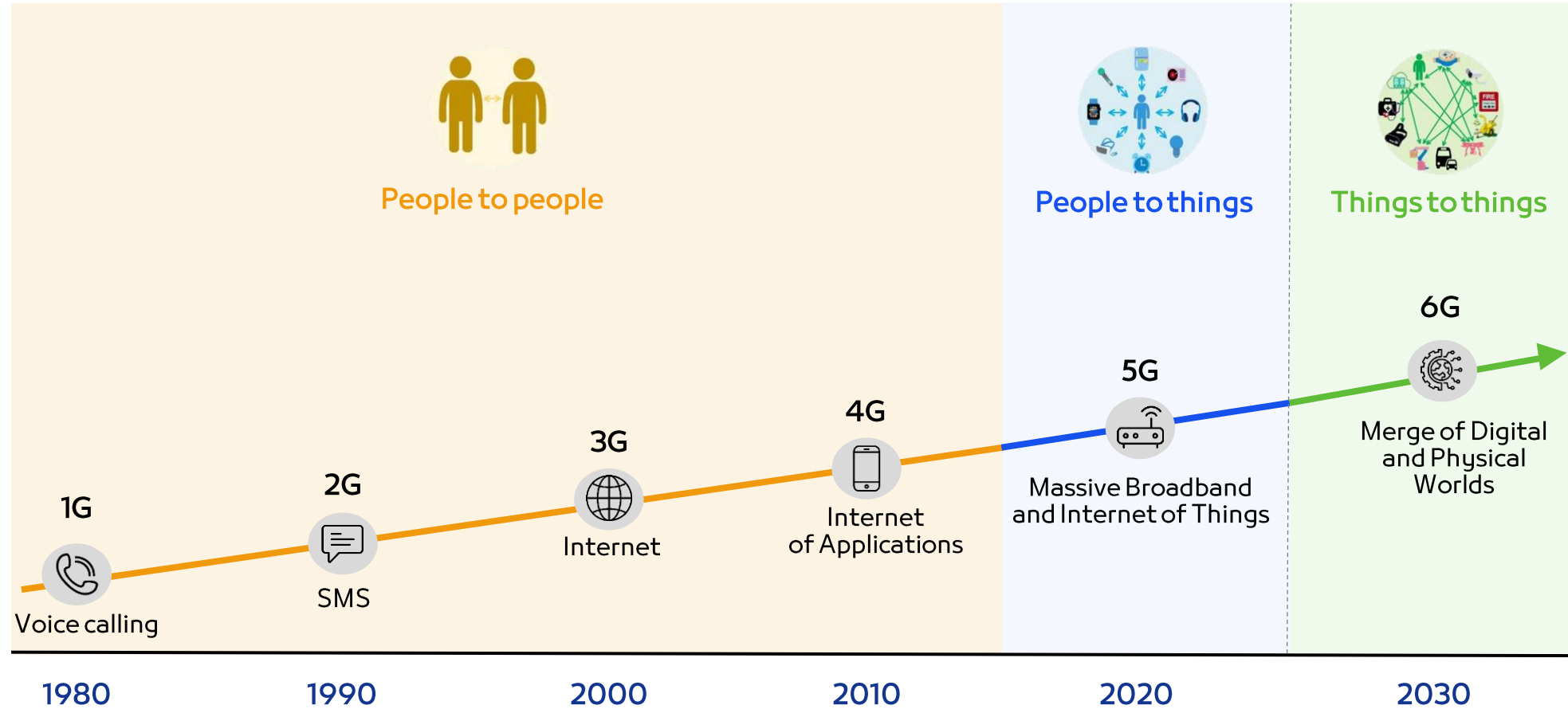
5 Impact

KSA can expect **a value of $45.5B** by 2035 through a designer/developer role

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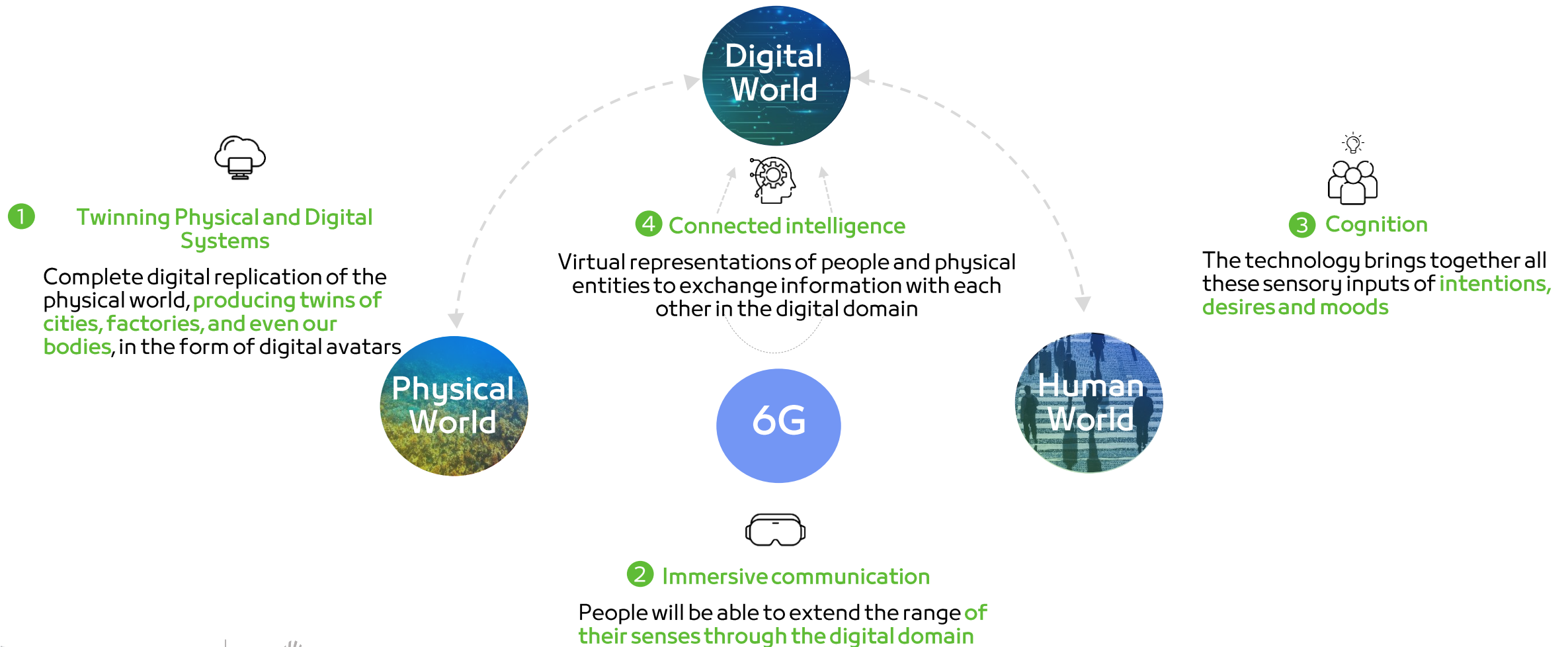
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What do we know about 6G technology and characteristics?

Intelligence

The common vision for 6G is to enable the merge of digital and physical worlds

People to people

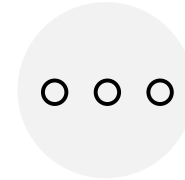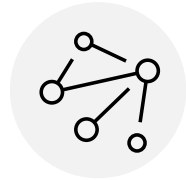**People to things**

Things to things

6G
Merge of Digital and Physical Worlds

5G
Massive Broadband and Internet of Things

4G
Internet of Applications

3G
Internet

2G
SMS

1G
Voice calling

1980 1990 2000 2010 2020 2030

There are four pillars enabling the merge of physical and digital worlds

Digital World

Physical World

6G

Human World

1 **Twinning Physical and Digital Systems**

Complete digital replication of the physical world, producing twins of cities, factories, and even our bodies, in the form of digital avatars

4 **Connected intelligence**

Virtual representations of people and physical entities to exchange information with each other in the digital domain

3 **Cognition**

The technology brings together all these sensory inputs of intentions, desires and moods

2 **Immersive communication**

People will be able to extend the range of their senses through the digital domain

Existing connectivity technology is not sufficient to support the merge

Connectivity challenges

Network latency and data rates	Predictable and accurate location positioning	Network with different environments	Edge computing enablement	Security and safety
The current latency and data rates are insufficient for upcoming applications (e.g. holographic remote surgery)	The current accuracy of 5G is insufficient to twin physical objects in the virtual world (i.e., 1 cm location accuracy)	Connectivity networks operate at the best effort basis especially when reconnecting from one network to another	Current uplink speeds limitations cause a speed bottleneck for edge computing development to serve downlink traffic	Networks lack necessary safety and security features to face dynamic threats

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To address these challenges, leading vendors defined R&D trends which will become the foundation for 6G

Technology trends

- From predefined services **to flexible user centricity**

- From manually controlled to **learning networks**

- From terrestrial 2D to **global 3D connectivity**

- From data management to **data ownership**

- From secure communication to **trustworthy platforms**

- From energy efficiency to **sustainable transformation**

6G foundation elements

Network reliability	AI native core	Interconnected devices
3D architecture	Security enhancements	Green low-carbon networks

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6G is expected to have characteristics overpassing any previous technology

Performance metrics	1G	2G	3G	4G	5G	6G
Peak Data Rate		50 kbps	21 Mbps	100 Mbps	20 Gbps	≥1 Tbps
Mobility				350 km/h	500 km/h	≥1000 km/h
Latency		300 ms	100 ms	10 ms	1 ms	10–100 μs
Connection Density			1x	10x	100x	1000x
Mbps/m^2			0.001	0.1	10	1000
Spectral Efficiency			0.6x	1x	3 x	≥15 x
Network Energy Efficiency		0.01 x	0.1 x	1x	≥10 x	≥100 x

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What will the 6G technology enable and how will it do so?

Insight

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6G enables digitalized physical world, Internet of Senses and connected intelligent machines

The Digitalized Physical World

Physical objects, humans, environments, and services will have a digital representation

Internet of Senses (IoS)

Users can interact with digital replicas of humans or objects in a real–time merged reality

Connected Intelligent Machines

Network AI to connect distributed intelligent agents in all industries

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However, the planned changes in 6G architecture will create challenges for countries and market players
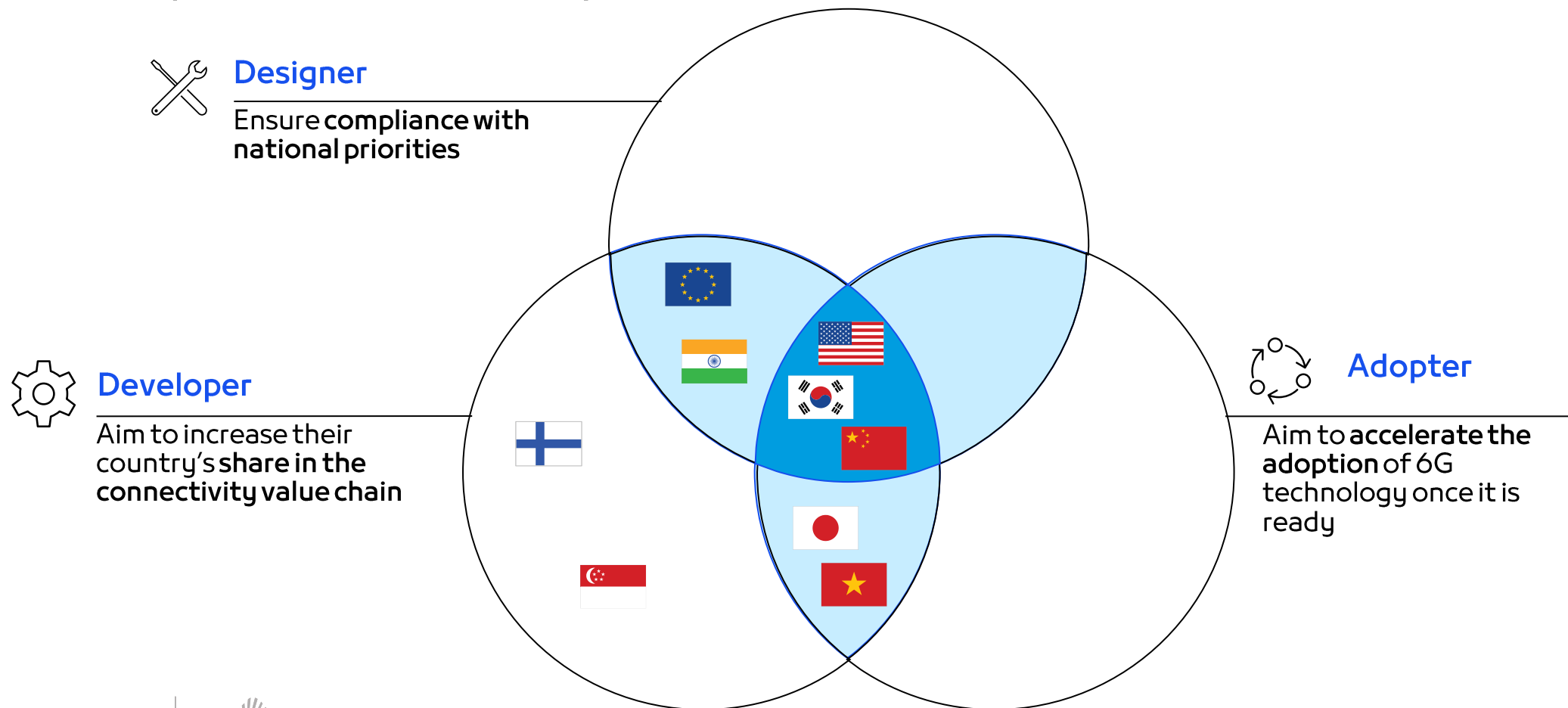
6G Challenges

- Integrated cellular and satellite networks present a risk of value leakage and revenue loss for cellular providers

- Globalization of network providers will create data sovereignty risks

- Increasing CAPEX for network rollout due to required network densification (e.g., 5G is 2x–6x more expensive than 4G)

- Big players in the market will not have the capacity to create and provide solutions for all tailored applications

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What are countries doing to address the 6G opportunity?

Innovation

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Roles for governments to play

Designer

Ensure **compliance with national priorities**

Developer

Aim to increase their country's **share in the connectivity value chain**

Adopter

Aim to **accelerate the adoption** of 6G technology once it is ready

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The EU launched the Hexa-X project for 6G in a designer and developer roles

Hexa-X project
Partners: Nokia, Ericsson

Vision on 6G
To connect human, physical and digital worlds with a fabric of 6G key enablers

Objectives
- Foundation for an end-to-end system architecture
- Connecting intelligence
- Impact creation

Designer
- Organization of public workshop
- Preparation of joint whitepapers
- Active participation in major events

Developer
- Development of the foundation and contribution to industry consensus leading to 6G

Adopter
- Not yet defined

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South Korea launched a 6G R&D in a designer, developer and adopter roles

6G R&D implementation plan
Partners: LG, Samsung, SK Telecom

Objectives
- Preemptive development of next–generation technologies, securing standard and high value–added patents, and laying R&D and industry foundations

- Five major areas for the pilot project:
  - Digital healthcare
  - Immersive content
  - Self-driving cars
  - Smart cities
  - Smart factories

Designer
- Aim to be the first one to roll out 6G in 2028
- Targeting leadership in international standards and patents, with an emphasis on active public–private cooperation in the early stages of 6G

Developer
- Investment of $194 Mn by 2025 in six focus areas (performance, Terahertz bands, space communications, ultra–precision; artificial intelligence; and reliability)
- Identifying technical requirements for key areas of the 6G network

Adopter
- To roll out additional pilot projects that include some of the use cases expected for 6G

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IMT-2030 (6G) Promotion Group
Partners: Huawei, ZTE

Objectives

- 6G expertise committee will focus on 5 key areas:
  - Requirements
  - Wireless
  - Network
  - Spectrum
  - Standards

- Promotion Group includes 57 members (research institutions, operators, system equipment providers, chipset/terminal providers, and universities)

Designer
- Focus on 6G vision and requirements
- Research topics including 6G spectrum requirements, propagation characteristics

Developer
- Promoting the research of 6G and building an international view exchange platform
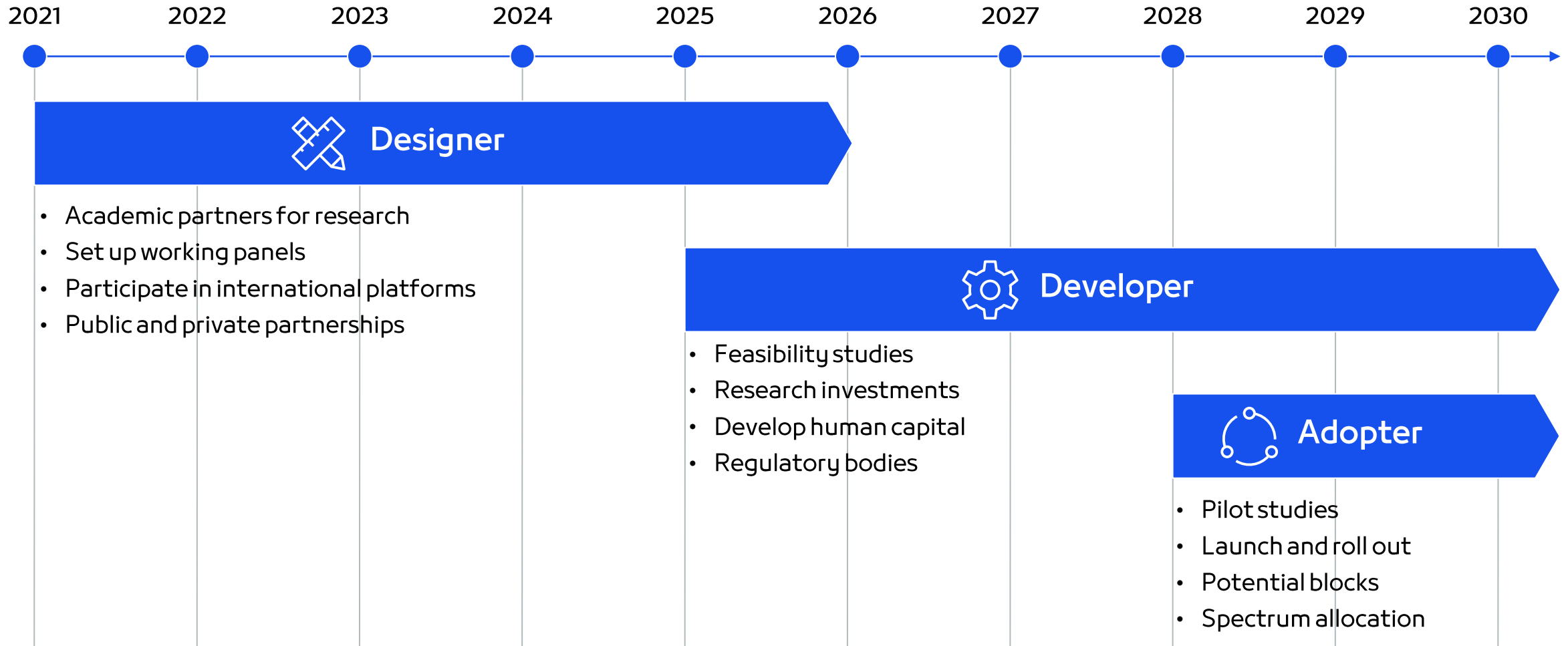
Adopter
- Deciding the vision for 6G by around 2023
- Set technological standards by 2026
- Rolling out relevant technology by 2028
- Commercial use of the network by 2030

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Who is involved in addressing the 6G opportunity?

Interaction

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Depending on the objectives, a role to play in 6G development can be chosen, which defines the time to enter the race

2021   2022   2023   2024   2025   2026   2027   2028   2029   2030

Designer

- Academic partners for research
- Set up working panels
- Participate in international platforms
- Public and private partnerships

Developer

- Feasibility studies
- Research investments
- Develop human capital
- Regulatory bodies

Adopter

- Pilot studies
- Launch and roll out
- Potential blocks
- Spectrum allocation

Initiatives that could be launched as a part of the 6G development program

		MCIT	CSTC	KAUST	Saudi Space Agency
Designer	Encourage academic 6G research			✓	✓
	Set up working panels on 6G vision and standards	✓	✓	✓	✓
	Engage in international 6G platforms	✓	✓		
Developer	Develop feasibility studies of 6G R&D programs	✓		✓	✓
	Invest in 6G technologies and patents	✓		✓	
	Boost public and private partnerships for 6G joint programs	✓			
	Collaborate with 6G national and international players	✓		✓	
	Train human capital on 6G technologies	✓			
Adopter	Launch pilot studies to test 6G technologies	✓	✓		✓
	Establish tech entrepreneurship programs to develop 6G pilot projects	✓			✓
	Set the timeline and roadmap for 6G rollout	✓	✓		
	Invest in 6G infrastructure	✓	✓		
	Allocate spectrum bands for 6G requirements		✓		
	Roll out 6G services with private and public entities	✓	✓		

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✓ Potential Stakeholder

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What value can be expected from 6G?

Impact

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There is a tremendous opportunity for 6G use cases which will support Vision 2030 by digital transformation. For example:

Industry and manufacturing

Digital transformation of manufacturing through cyber physical systems and IoT services

Smart transportation

Evolution of automotive industry to support infotainment and automated driving

Financial services

Evolution of financial sector through high-frequency trading and blockchain technology

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Source: Bertin, Emmanuel, et al. Shaping Future 6G Networks: Needs, Impacts, and Technologies. John Wiley & Sons, Incorporated, 2021.
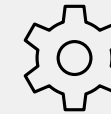
Saudi Arabia's 6G market ($ billion)

■ Adopter
■ Designer/Developer

1.5x higher value
if KSA becomes a technology designer/developer vs an adopter

Year	Adopter	Designer/Developer
2030	0.1	0.6
2031	0.4	1.4
2032	1.4	3.5
2033	4.3	8.5
2034	11.4	19.1
2035	30.3	45.5
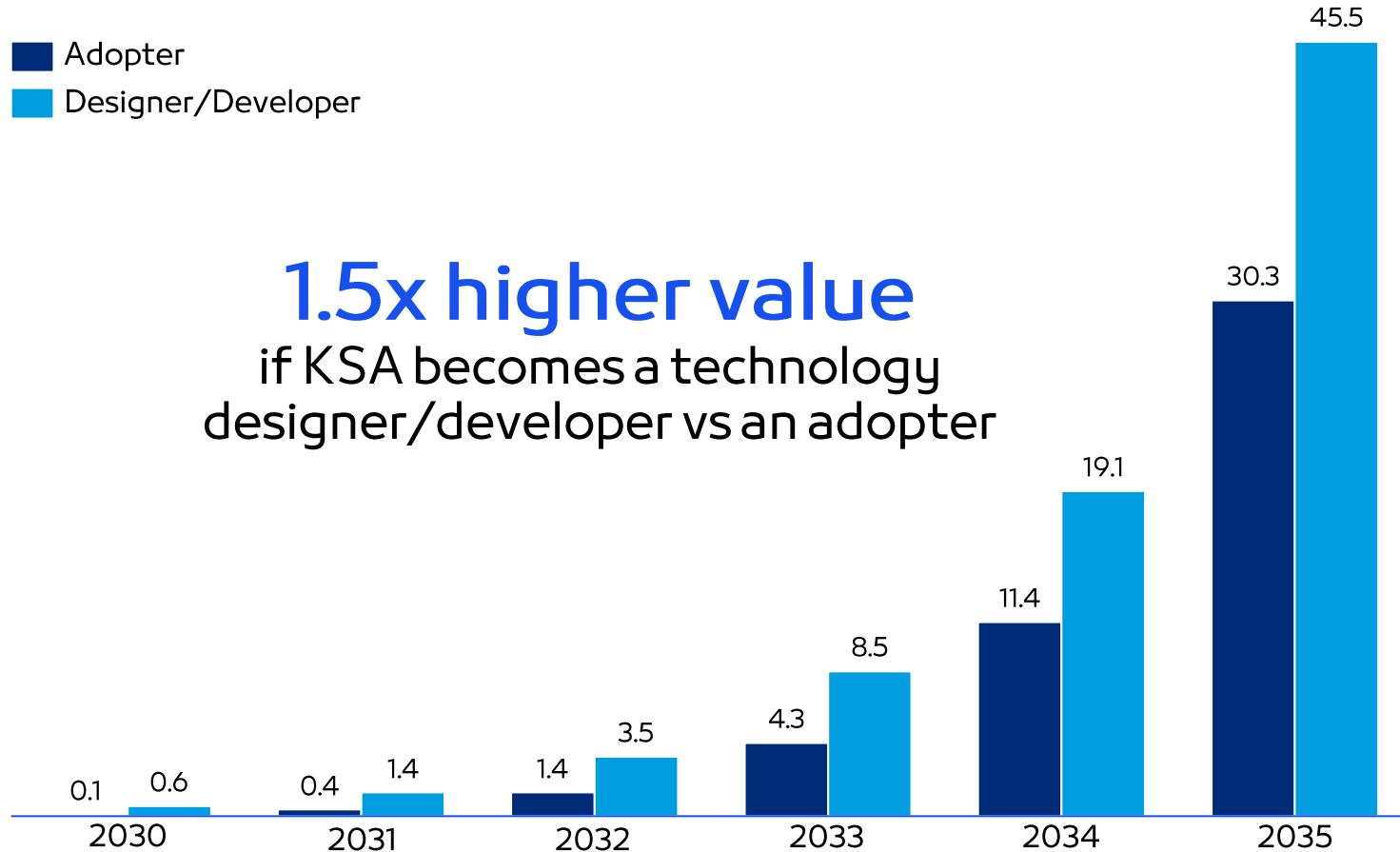
Adopter
- 6G Adopter scenario is based on the KSA historical 5G development trend, applied to the expected 6G market

Designer/Developer
- "Developer" countries (e.g., South Korea) generally experience faster market growth, especially in the initial years of adoption
- 6G Developer scenario is based on the South Korea and China 5G development trends

Source: BIS Research, Brandessence Market Research.

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Thank you

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