CHAPTER 2

Accelerating the transition to IPv6

THE BOTTOM LINE

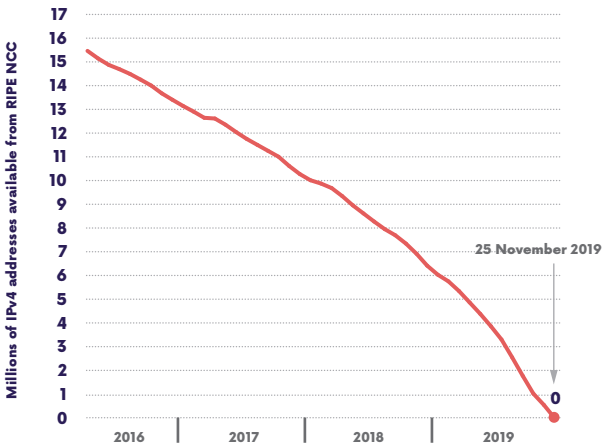
- **The** transition to IPv6 has become a pressing issue, to prevent the internet from being split into two: IPv4 on the one side and IPv6 on the other.
- As of mid-2023, **81% of residential fixed access customers** (FttH, cable, ADSL) were IPv6-enabled, **versus 66% of mobile network customers.** Arcep has nevertheless observed **sizeable disparities between operators,** particularly in terms of enabling IPv6 on business plans.
- Of the 100 countries with the most internet users, **France gets the bronze medal for IPv6 adoption,** with a combined residential and business adoption rate estimated at 64.6% in April 2024, behind India (71.2%) and Malaysia (65.5%).
- The **percentage of mail hosting companies' IPv6-enabled addresses** has **more than doubled in the past 12 months,** going from 8% to 19% between mid-2022 and mid-2023.
- Arcep hosts the **IPv6 task force** and in 2023 co-hosted a workshop on the development and advances in IPv6 in France. **Training videos** on the technical aspects of IPv6 were produced for the event.

1. ACCELERATING THE TRANSITION TO IPv6: KEY TO SAFEGUARDING COMPETITION AND INNOVATION

Every device connected to the internet has an IP address. Public IP addresses are registered and routable on the Web, and are therefore unique worldwide identifiers. IPv4, which has been used on the internet since 1 January 1983, provides an addressing scheme of close to 4.3 billion IP addresses. But the overwhelming success of the Web, the range of uses and the proliferation of connected objects have led directly to the **gradual exhaustion of IPv4 addresses**. Since 25 November 2019, RIPE NCC (the regional internet registry that allocates IPv4 addresses in Europe and the Middle East) has been suffering a shortage of IPv4 addresses.

To tackle this situation, IPv6 specifications were finalised in 1998. They incorporate functions for increasing security by default and optimising routing. Above all, IPv6 delivers an almost infinite number of IP addresses: 667 million IPv6 addresses for each square millimetre of the earth's surface.

HISTORY OF IPv4 ADDRESS EXHAUSTION



Source: RIPE-NCC data

This sluggish pace of IPv6 development creates a **risk of seeing the Internet split in two, with IPv4 on one side and IPv6 on the other**. To give an example, if a website or an application is hosted in IPv6-only, that means it cannot be accessed by users who only have an IPv4 address.

This shortage of IPv4 addresses, and the ensuing risks, make **the transition to the new internet communication protocol an especially pressing issue**.

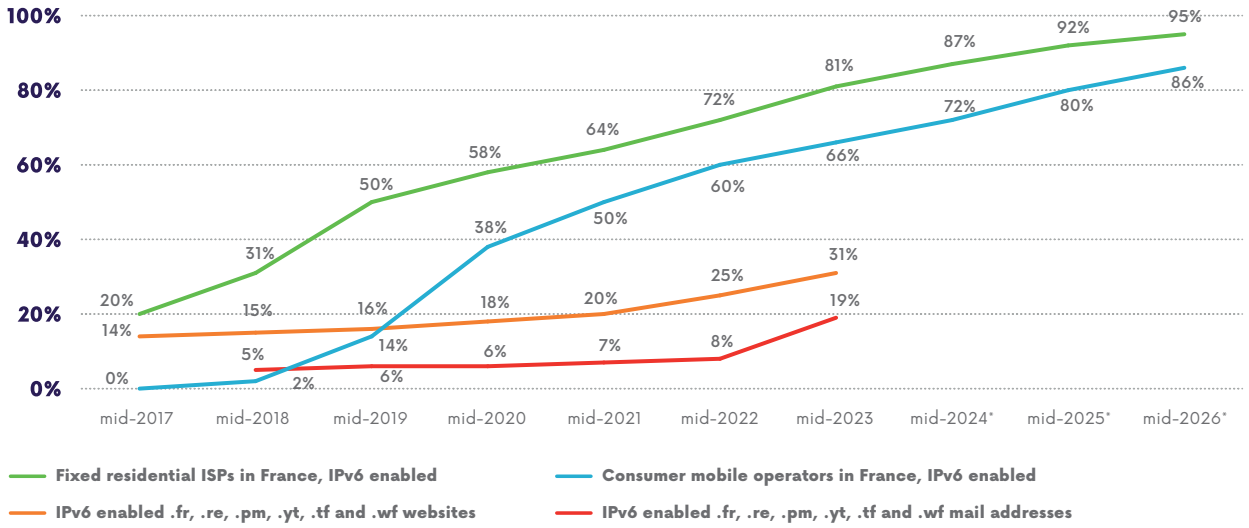
To assess IPv6 deployment in France, Arcep uses data collected in accordance with its Decision No. 2023-0543 along with data from Afnic to produce an annual Barometer of the transition to IPv6, providing an overview of IPv6 adoption in France. This Chapter shares the main findings of the 2024 edition.

2. STATE OF THE TRANSITION TO IPv6 IN 2023

2.1. A plethora of players, all at different stages in their transition

Operators are making the transition to IPv6 more rapidly than web hosting companies and other content providers. As of mid-2023, 81% of residential Internet service providers' customers were IPv6-enabled, versus 66% of mobile customers. Looking at content providers and hosting companies, 31% of websites are IPv6-ready (19% for email addresses). If these figures are low, there has been a notable uptick in the pace of the transition: for mail, the rate of IPv6 readiness has more than doubled in the past 12 months. And almost all residential customers are expected to be IPv6-enabled by 2030[1].

STATUS OF THE TRANSITION TO IPv6 IN FRANCE



*Figures subject to change (operator forecasts, except for Free mobile: Arcep forecasts)

Operator source: data from end of June 2023, collected by Arcep from the main operators and aggregated according to market share as of Q3 2022. For the sake of the analysis, the assumption is that Android has a 70% market share and iOS 30%. Website and mail source: Afnic data from October 2023

1 On fixed networks, by 2026, customers that do not have access to IPv6 will be on networks at the end of their life (ADSL/VDSL/cable), but the copper network is due to be switched off by 2030. On mobile networks, with the exception of Free, it is mainly old devices that are not IPv6-enabled which should gradually be phased out of the fleet.

2.2. Fixed ISPs

According to forecasts provided by operators, **the transition to IPv6 amongst residential customers should be virtually complete in 2030** with the switchoff of the copper network: some operators have chosen not to migrate infrastructures that are coming to the end of their life to IPV6. The transition for internet plans designed for businesses and professionals could take a few years longer.

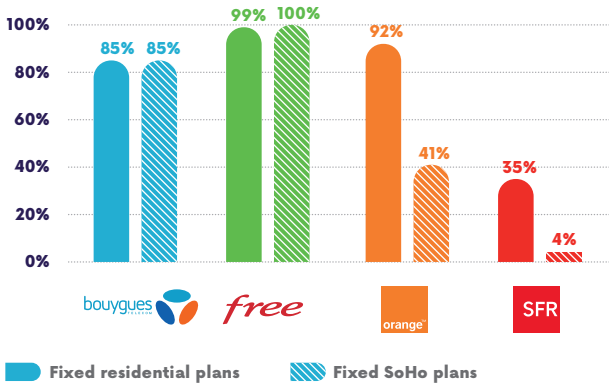
On **residential fixed networks,** Arcep notes significant disparities between the main French telecom operators' transition to IPv6:

- **Bouygues Telecom** enables IPv6 for all of its residential FttH, ADSL, VDSL, 4G box and 5G box customers with a compatible router/STB and connected to its own network. IPv6 not yet available for ADSL or VDSL on a third-party backhaul network (it is Bouygues Telecom customers who are connected to an Orange DSLAM).
- **Free** enables IPv6 for all of its residential FttH, ADSL, VDSL customers connected to its own network. IPv6 not available for ADSL or VDSL on a third-party backhaul network (aka non "unbundled" customers) nor on Free's 4G+ box/router.
- **Orange** enables IPv6 for all of its residential FttH, ADSL, VDSL, 4G Home and 5G Home box customers with a compatible router/STB and connected to a network that assigns its DHCP addresses. IPv6 not available for some residential ADSL customers (addresses assigned via PPP). Added to which, all new customers' addresses are assigned by DHCP scope.
- **SFR** is phasing out the replacement of network equipment that was not IPv6-compatible on the FttH network. IPv6 is not systematically enabled: it is therefore left up to the customer to configure their router. At a time when the copper access is gradually being switched off, in 2023 SFR elected to eliminate IPv6 support on ADSL/VDSL plans. IPv6 (encapsulated in IPv4) had previously been available with ADSL and VDSL plans, but not enabled by default (at the end of June 2022, 1% of ADSL and VDSL customers had enabled this option). IPv6 is also not available on the operator's cable network.

For **"Pro" plans** designed for small businesses (SoHos), operators emulate residential market strategies, with two exceptions:

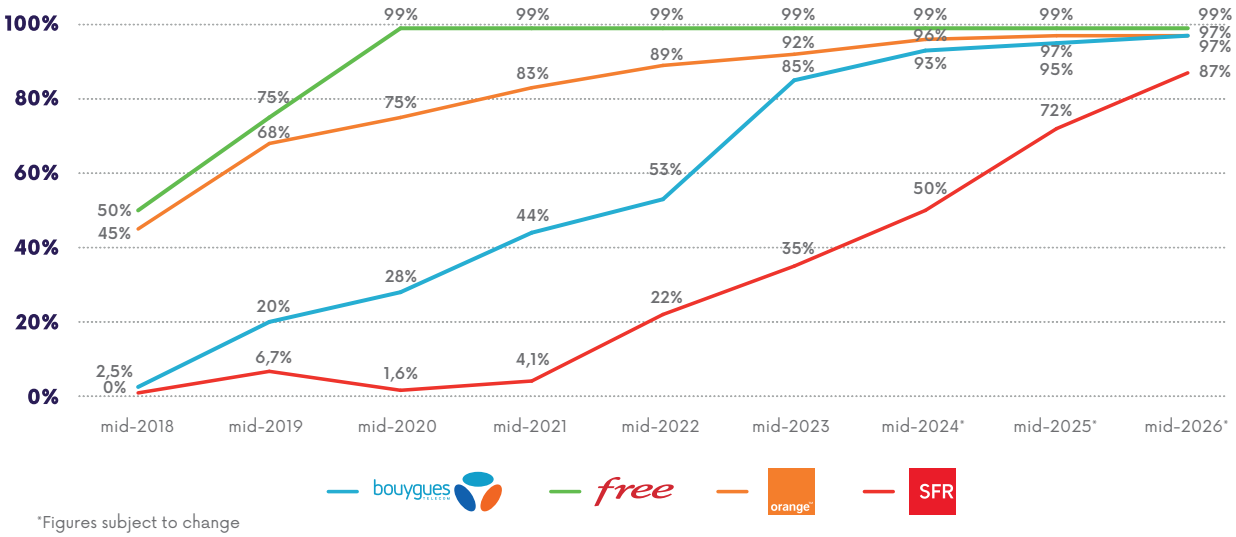
- **Orange:** IPv6 is not made available to ADSL or VDSL "Pro" small business customers;
- **SFR:** IPv6 is only available for fixed 4G and 5G plans (no IPv6 for FttH, ADSL, VDSL or cable plans for small businesses).

FIXED NETWORKS: PERCENTAGE OF IPv6-ENABLED CUSTOMERS



Source: Data as of end of June 2023, collected by Arcep from operators

RESIDENTIAL FIXED NETWORK: PROGRESSION OF IPv6-ENABLED CUSTOMERS



*Figures subject to change

Source: Data as of end of June 2023, collected by Arcep from operators

2.3. Mobile ISPs

According to the forecasts provided by Bouygues Telecom, Orange and SFR, smartphones' transition to IPv6 (i.e. that are not IPv6-enabled by default) should be complete in 2030, for both consumer and business customers. The transition could take longer for "data only" plans (4G/5G portable routers, tablets, computers, etc…).

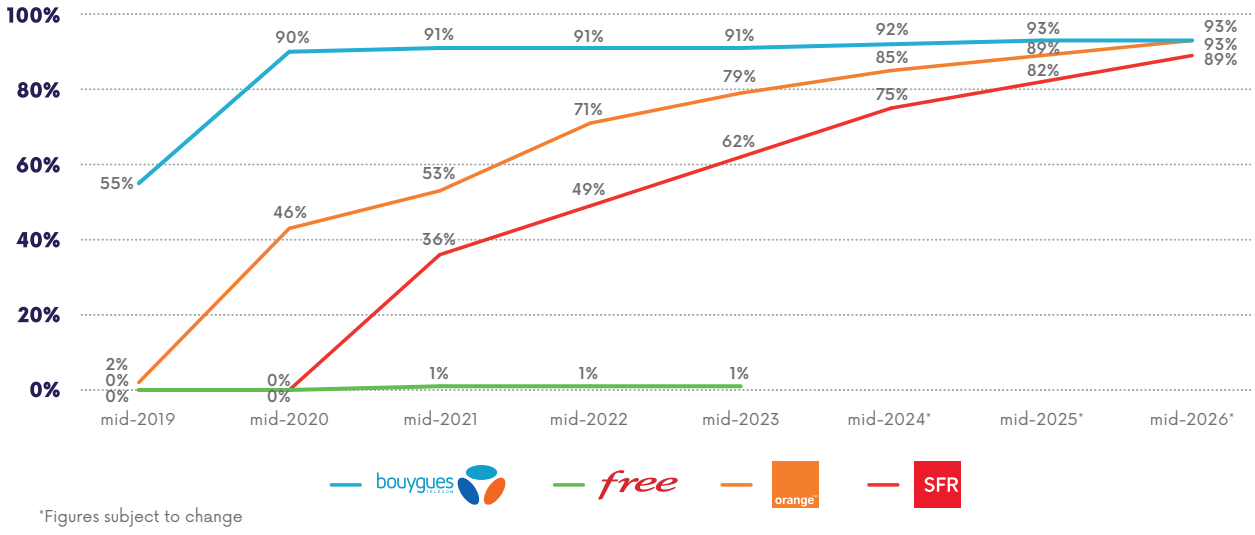
Free is not able to provide forecasts for upcoming IPv6 enablement rates.

Arcep has observed sizeable **disparities in consumer** mobile plans' transition to IPv6. If all of the main operators offer IPv6, there are real differences in their approach to enabling the protocol:

- **Android:** Bouygues Telecom, Orange and SFR all enable IPv6 by default on Android phones released after 2018 (Bouygues), 2020 (Orange) or 2021 (SFR). Free does not enable IPv6 by default. Customers need to enable IPv6 manually in their account space, then on their Android phone (unless they have a smartphone that was released after July 2022);
- **iPhone:** Bouygues Telecom, Orange and SFR all enable IPv6 by default on iPhones with at least iOS 12.2 (Bouygues), iOS 13.0 (Orange for iPhone 7 and more recent), iOS 14.3 (SFR), or iOS 15.4 (Orange for iPhone 6S and SE). Free does not enable IPv6 by default. Customers need to enable IPv6 manually in their account space, and to have downloaded at least iOS 15.4.

For "Pro" **small business plans, Bouygues Telecom, Orange and SFR** offer IPv6 under the same terms as consumer plans; **Free Pro** plans still do not offer IPv6.

CONSUMER MOBILE NETWORK: PERCENTAGE OF IPv6-ENABLED CUSTOMERS



*Figures subject to change

Source: Data as of end of June 2023, collected by Arcep from operators and aggregated. The assumption is that Android has a 70% market share and iOS 30%.

MOBILE NETWORK: PERCENTAGE OF IPv6-ENABLED CUSTOMERS

Source: Data as of end of June 2023, collected by Arcep from operators and aggregated. The assumption is that Android has a 70% market share and iOS 30%.

2.4. Web hosting companies

A website is considered accessible in IPv6 when it has a DNS IPv6 registration. To exclude a portion of the unused domain names, the rate is calculated using only domain names with an HTTPS certificate, i.e. 2.4 million of them with domain names ending in .fr, .re, .pm, .yt, .tf and .wf are analysed below.

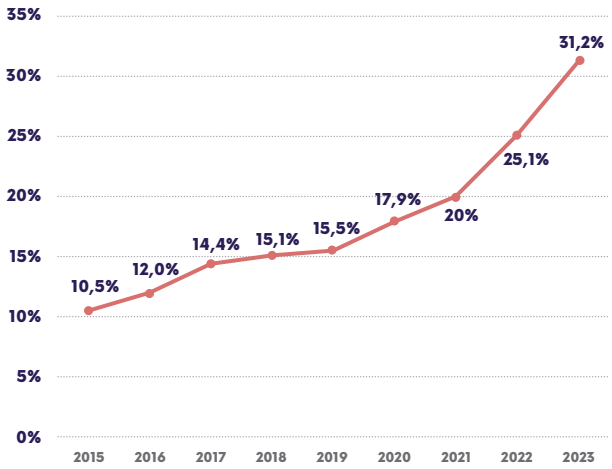
In October 2023, web hosting companies were one of the weakest links in the migration to IPv6. **Only 31.2% of websites are in fact IPv6-ready.** It is nevertheless worth noting the steady rate of increase: up six points since October 2022 and 11 points since 2021. More domain names were IPv6-enabled over the past two years than between 2015 and 2021.

Among the top 10 web hosting companies in France, IONOS, LWS, Infomaniak and Cloudflare are reporting that more than half the websites they host are IPv6-enabled.

Data on all .fr, .re, .pm, .yt, .tf and .wf web hosting companies are available in three formats: PDF, OpenDocument (can be read with LibreOffice Calc or Excel) and CSV raw data.

PROGRESSION OF IPv6-ENABLED WEBSITES

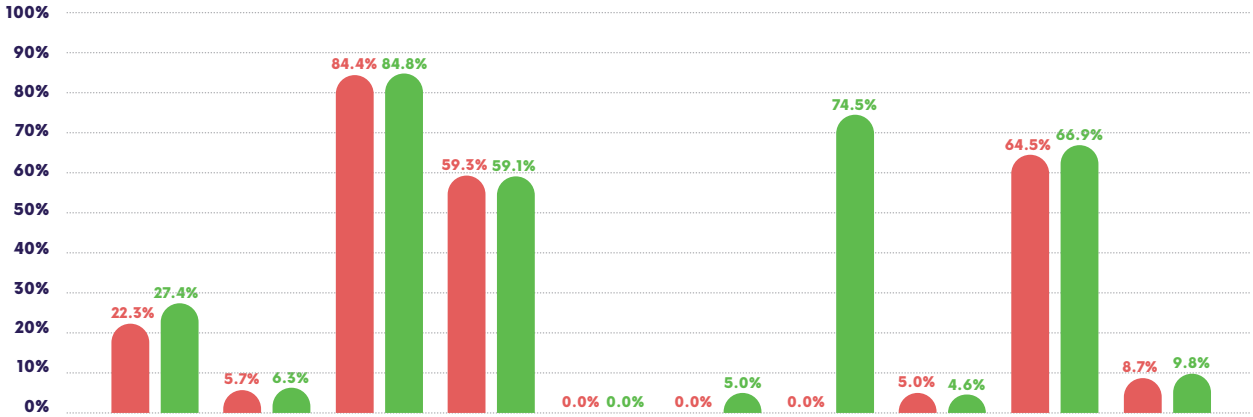
for .fr, .re, .pm, .yt, .tf and .wf domain names



Source: Afnic data as of October 2023.

TAUX DE SITES WEB ACCESSIBLES EN IPv6

sur les noms de domaine .fr, .re, .pm, .yt, .tf et .wf



No. of domain names	OVHcloud AS16276	Amazon AWS AS16509	IONOS by 1&1 AS8560	Cloudflare AS13335	o2switch AS50474	Google Cloud AS396982	LWS AS210403	Gandi AS29169	Infomaniak AS29222	Scaleway AS12876
- 2022	914,545	162,338	165,455	123,076	97,415	25,694	63,803	49,808	42,355	46,697
- 2023	928,130	185,553	181,318	160,590	119,967	92,612	63,000	49,455	48,585	43,791

Source: Afnic data as of October 2023. Only domain names with a valid TLS certificate are counted.

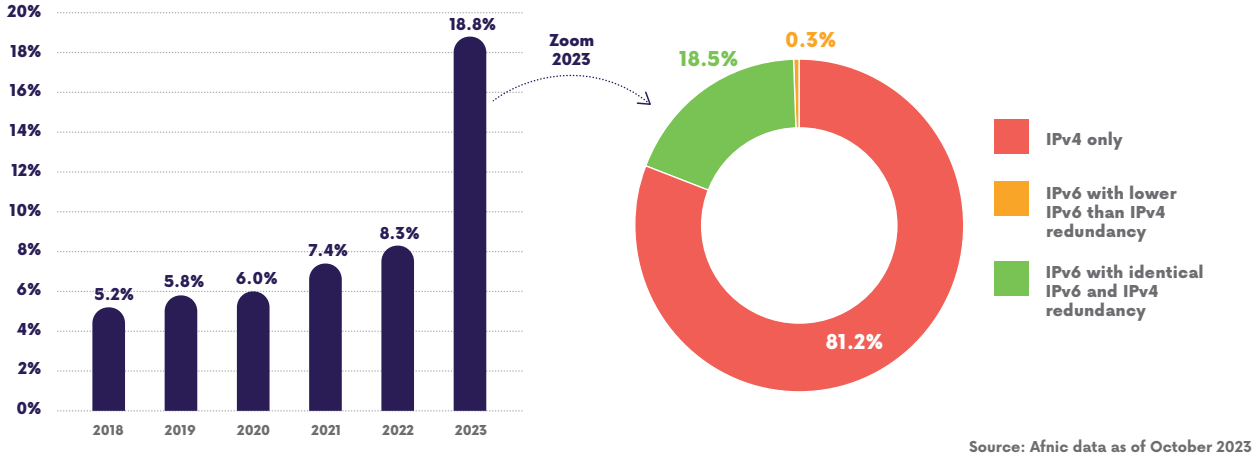
2.5. Mail hosting companies

Mail hosting servers also lag very far behind in the transition: only 18.8% of mail servers currently use IPv6[2] addresses. There has nevertheless been a **considerable increase** since 2022: the number of IPv6-enabled mail servers has more than doubled in 12 months, from 8% to 19%. This percentage still remains very small, compared to the other links in the internet chain.

Looking at the top 10 players in terms of domain name numbers, Google, Infomaniak, Cloudflare and Gandi rank highest, each with more than 94% of domain names for mail using IPv6.

PERCENTAGE OF WEB MAIL ACCESSIBLE IN IPv6

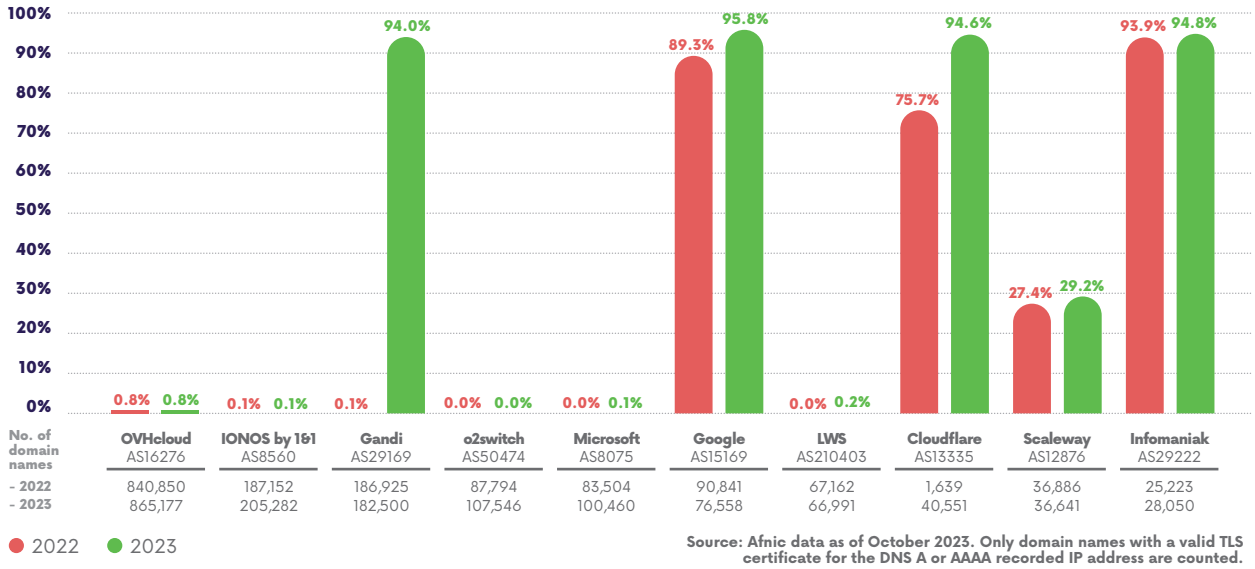
for .fr, .re, .pm, .yt, .tf and .wf domain names



Source: Afnic data as of October 2023

PERCENTAGE OF IPv6-ENABLED MAIL SERVERS

for .fr, .re, .pm, .yt, .tf and .wf domain names



No. of domain names	OVHcloud AS16276	IONOS by 1&1 AS8560	Gandi AS29169	o2switch AS50474	Microsoft AS8075	Google AS15169	LWS AS210403	Cloudflare AS13335	Scaleway AS12876	Infomaniak AS29222
- 2022	840,850	187,152	186,925	87,794	83,504	90,841	67,162	1,639	36,886	25,223
- 2023	865,177	205,282	182,500	107,546	100,460	76,558	66,991	40,551	36,641	28,050

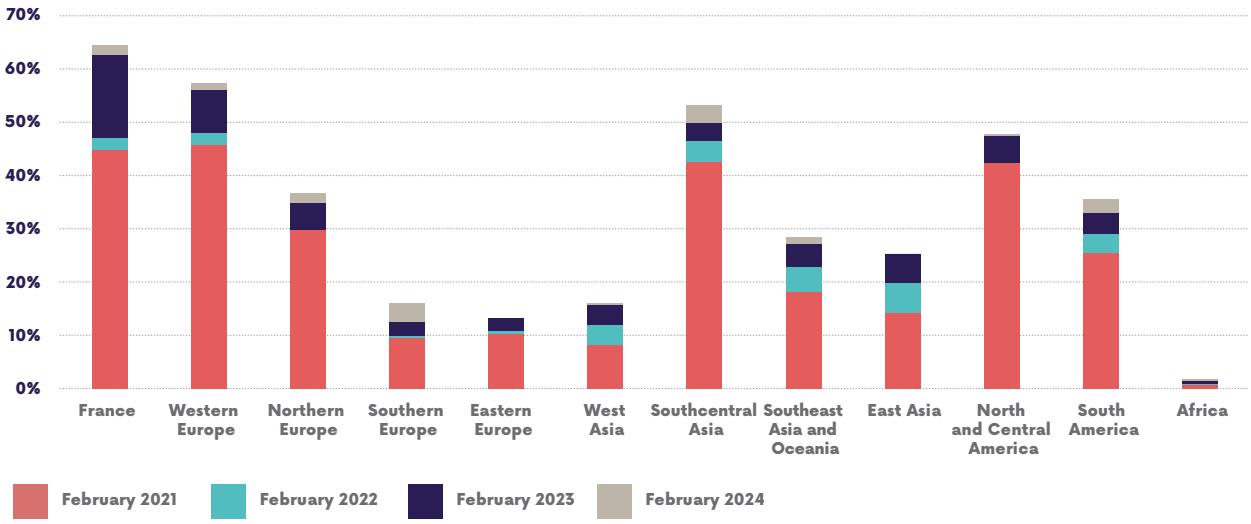
Source: Afnic data as of October 2023. Only domain names with a valid TLS certificate for the DNS A or AAAA recorded IP address are counted.

2 To exclude a portion of the unused domain names, only the 2.1 million websites with domain names ending in .fr, .re, .pm, .yt, .tf and .wf that met the dual condition of valid HTTPS hosting and mail hosting were considered.

3. THE TRANSITION TO IPv6 AROUND THE WORLD

Arcep has created an interactive map that lets users both view the rate of IPv6 adoption in the 100 countries with the most internet users, and see how the rankings have changed over time. In April 2024 **the IPv6 adoption rate** represents the percentage of IPv6-enabled users, through their ISP's network, measured at the hosting company (which is already IPv6-enabled) level. It therefore provides an idea of the status of devices' and internet service providers' (residential and business, fixed and mobile) transition. France **ranks number three worldwide (64.6%),** behind India (71.2%) and Malaysia (65.5%).

REGIONAL IPv6 ADOPTION RATE



Source: February 2024 IPv6 data from Google, Akamai, Facebook and Apnic. Only the 100 countries with the most internet users are considered. The median of the four sources is calculated for each country, before being aggregated, prorated by the number of internet users in each region.

THE VIEW FROM ABROAD: THE CZECH REPUBLIC'S INITIATIVE TO SHUT DOWN IPv4 IN 2032:

The **Czech Government** asked the public sector to stop providing e-government services using IPv4 **as of 6 June 2032.** Internet users who are not IPv6-ready in 2032 will no longer have access to Czech government websites, and business applications are going to follow suit and shut down IPv4 at the same time. A countdown has been created online.

WORK BEING DONE BY THE IPv6 TASK FORCE

Since 2019, Arcep has been heading up the IPv6 task force, in collaboration with Internet Society France. Open to all internet ecosystem players (telcos, hosting companies, businesses, public sector, etc.), this task force meets once a year, and is geared to bolstering the transition to IPv6 by giving participants an opportunity to discuss specific issues and to share best practices.

To contribute to the effort to achieve "Widespread awareness of IPv6" mentioned in the Government report on the status of IPv6 deployment in France of June 2016, the task force released four short videos, produced by the École Polytechnique, IMT Atlantique and Jean-Charles Bisecco, expert member from the IPv6 task force:

- **IPv6 and Internet of Things:** 6LoWPAN, RPL, Matter, LPWAN and SCHC by IMT Atlantique (Laurent Toutain, Pascal Thubert, David Le Goff and Rémi Demerlé): video.
- **SRv6** (*Segment Routing over IPv6 dataplane*): introduction to the protocol, by the Institut Polytechnique de Paris (Kevin Jiokeng and Thomas Clausen): video.
- **SRv6** (*Segment Routing over IPv6 dataplane*): deployment strategy, by Jean-Charles Bisecco: presentation - video.
- **BIERv6** (*Bit Index Explicit Replication IPv6 encapsulation*) by Institut Polytechnique de Paris (Kevin Jiokeng and Thomas Clausen): video.

On 7 December 2023, IDATE, Arcep and IPv6 Forum hosted a workshop in Arcep's offices on the development and advances in IPv6 in France. The workshop provided an opportunity for expert-led discussions. Arcep Executive Board member, Serge Abiteboul, and IDATE President and CEO, Jean-Luc Lemmens, kicked off the workshop by underscoring the importance of the transition to IPv6: *"The goal is not to keep two protocols. The goal is to shut down IPv4 at some point. We're not there yet, but we do have to prepare for it. We need to map out shutdown scenarios to know how we can manage, in a not too distant future, to shut down IPv4 completely"*. (video).

Videos of the workshop can be viewed on the Arcep website. One of the most popular is of Bouygues Telecom explaining solutions for sharing IPv4 between multiple customers.

This workshop will be held again in 2024.

↑ Photo of Serge Abiteboul, member of the Arcep Executive Board, delivering the opening remarks at the "IPV6 France" workshop on 7 December 2023.

Lexicon

Afnic (Association française pour le nommage internet en coopération)
France's domain name registry. A non-profit organisation (under France's law of 1901) whose mandate is to manage top-level domain names in France (.fr), Reunion (.re), France's southern and Antarctic territories (.tf), Mayotte (.yt), Saint-Pierre-et-Miquelon (.pm) and Wallis-et-Futuna (.wf).

API (Application Programming Interface)
Application Programming Interface that enables two systems to interoperate and talk to one another without having been initially designed for that purpose. More specifically, a standardised set of classes, methods or functions through which a software programme provides services to other software.

NRA (National Regulatory Authority)
an organism or organisms that a BEREC Member State mandates to regulate electronic communications.

BEREC (Body of European Regulators for Electronic Communications)
independent European body created by the Council of the European Union and the European Parliament, and which assembles the electronic communications regulators from the 27 European Union Member States.

CDN *(Content Delivery Network)*
Internet Content Delivery Network.

On-net CDN
CDN located directly in an ISP's network.

Codec
a device or computer program that encodes or decodes a digital data stream, for transmission or storage purposes.

Cross-traffic
the traffic generated during a QoS and/or QoE test by an application other than the one being used to perform the test, either on the same device or on another device connected to the same box. Cross-traffic decreases the bandwidth available for the test.

Speed
Also referred to as throughput. Quantity of digital data transmitted within a set period of time. Connection speeds or bitrates, are often expressed in bits per second (bit/s) and its multiples: Mbit/s, Gbit/s, Tbit/s, etc. It is useful to draw a distinction between the speed at which data can be:
- received by a piece of terminal equipment connected to the internet, such as when watching a video online or loading a web page. This is referred to as download or downlink speed;
- sent from a computer, phone or any other piece of terminal equipment connected to the internet, such as when sending photos to an online printing site. This is referred to as upload or uplink speed.

DNS (Domain Name System)
mechanism for translating internet domain names into IP addresses.

Dual stack
assigning both an IPv4 address and an IPv6 address to a device on the network.

ISP
Internet Service Provider.

CAP
content (web pages, blogs, videos) and/or application (search engine, VoIP applications) providers.

FttH (Fiber to the Home) network
very high-speed electronic communications network, where fibre is pulled right into the customer's premises.

HTTP (Hypertext Transfer Protocol)
client-server communication protocol developed for the World Wide Web.

HTTPS: HTTP Secured thanks to the use of SSL (secure socket layer) or TLS (transport layer security) protocols.

iOS
mobile operating system developed by Apple for its mobile devices.

IP (Internet Protocol)
communication protocol that enables a single addressing service for any device used on the internet. IPv4 (IP version 4) is the protocol that has been used since 1983. IPv6 (IP version 6) is its successor.

IPv6-enabled
device or connection that actually transmits and receives traffic using IPv6 routing, either thanks to activation by the customer or activation performed by the operator.

IPv6-ready
device or connection that is compatible with IPv6, but on which IPv6 is not necessarily activated by default.

IXP (Internet Exchange Point), or GIX (Global Internet Exchange)
physical infrastructure enabling the ISPs and CAPs connected to it to exchange internet traffic between their networks thanks to public peering agreements.

NAT
Network Address Translation mechanism for remapping one IP address space to another, used in particular to limit the number of public IPv4 addresses being used.

OS (Operating System)
software that runs a peripheral device, such as Windows, Mac OS, Linux, Android or iOS.

Peering
the process of exchanging internet traffic between two peers. A peering link can be either free or paid (for the peer that sends more traffic than the other peer). Peering can be public, when performed at an IXP (Internet Exchange Point), or private when over a PNI (Private Network Interconnect), in other words a direct interconnection between two operators.

Network termination point
the physical location at which a user gains access to public electronic communications networks.

QoS (Quality of Service): in Chapter 1, quality of service on the internet as measured by "technical" indicators such as download or upload speed, latency and jitter. The term QoS is often used to refer to both technical quality and quality of experience (QoE).

RFC (Request For Comments): official memorandum that describes the technical aspects and specifications that apply to the working of the internet or to different computer hardware.

Specialised service: electronic communication service(s) that are distinct from internet access services, and which require specific quality of service levels.

Autonomous Systems: a collection of networks managed by the same administrative entity, having relatively homogeneous routing protocols.

Web tester: tool for measuring QoS and QoE which is accessed through a website.

TLS (Transport Layer Security): used for encrypting internet exchanges and server authentication.

Transit provider: company that provides transit services.

Transit: Bandwidth that one operator sells to a client operator, providing access to the entire internet as part of paid, contractual service.

UDP (User Datagram Protocol): simple, connectionless (i.e. no prior communication required) transmission protocol, which makes it possible to transmit small quantities of data rapidly. The UDP protocol is used on top of IPv4 or IPv6.

VoIP (Voice over IP): Technology for relaying voice calls over IP-compatible networks via the internet.

VPN (Virtual Private Network): Inter-network connection for connecting two local networks using a tunnel protocol.

WAN (Wide Area Network): in this report, WAN refers to the internet network, as opposed to a LAN (local area network).

Wehe: Android and iOS application, developed by Northeastern University in partnership with Arcep, to detect traffic management practices that are in violation of net neutrality rules.

Wi-Fi: wireless communication protocol governed by IEEE 802.11 group standards.

xDSL (Digital Subscriber Line): electronic communications technologies used on copper networks that enable ISPs to provide broadband or superfast broadband internet access. ADSL2+ and VDSL2 are the most commonly used xDSL standards in France for providing consumer access.

Zero-rating: a pricing practice that allows subscribers to use one or more particular online applications without the traffic being counted against their data allowance.

3GPP: The 3rd Generation Partnership Project (3GPP) is a collaboration between standardization and normalization bodies that develops technical specifications for mobile networks.

4G: the fourth generation of mobile telephony standards. It is defined by 3GPP Release 8 standards.

5G: the fifth generation of mobile telephony standards. It is defined by 3GPP Release 15 standards.

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ARCEP, NETWORKS AS A COMMON GOOD

Internet, fixed and mobile telecom, postal and print media distribution networks constitute the “Infrastructures of freedom”. Freedom of expression, freedom to communicate, freedom to access knowledge and to share it, but also freedom of enterprise and innovation, which are key to the country’s ability to compete on the global stage, to grow and provide jobs.

Because it is essential in all open, innovative and democratic societies to be able to enjoy these freedoms fully, national and European institutions work to ensure that these networks develop as a “common good”, regardless of their ownership structure, in other words that they meet high standards in terms of accessibility, universality, performance, neutrality, trustworthiness and fairness.

Democratic institutions therefore concluded that independent state intervention was needed to ensure that no power, be it economic or political, is in a position to control or hinder users’ (consumers, businesses, associations, etc.) ability to communicate with one another.

The electronic communications, postal and print media distribution regulatory Authority (Arcep), a neutral and expert arbitrator with the status of quasi autonomous non-governmental organisation, is the architect and guardian of communication networks in France.

As network architect, Arcep creates the conditions for a plural and decentralised network organisation. It guarantees the market is open to new players and to all forms of innovation, and works to ensure the sector’s competitiveness through pro-investment competition. Arcep provides the framework for the networks’ interoperability so that users perceive them as one, despite their diversity: easy to access and seamless. It coordinates effective interaction between public and private sector stakeholders when local authorities are involved as market players.

As network guardian, Arcep enforces the principles that are essential to guaranteeing users’ ability to communicate. It oversees the provision of universal services and assists public authorities in expanding digital coverage nationwide. It ensures users’ freedom of choice and access to clear and accurate information, and protects against possible net neutrality violations. From a more general perspective, Arcep fights against any type of walled garden that could threaten the freedom to communicate on the networks, and therefore keeps a close watch over the new intermediaries that are the leading Internet platforms.

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