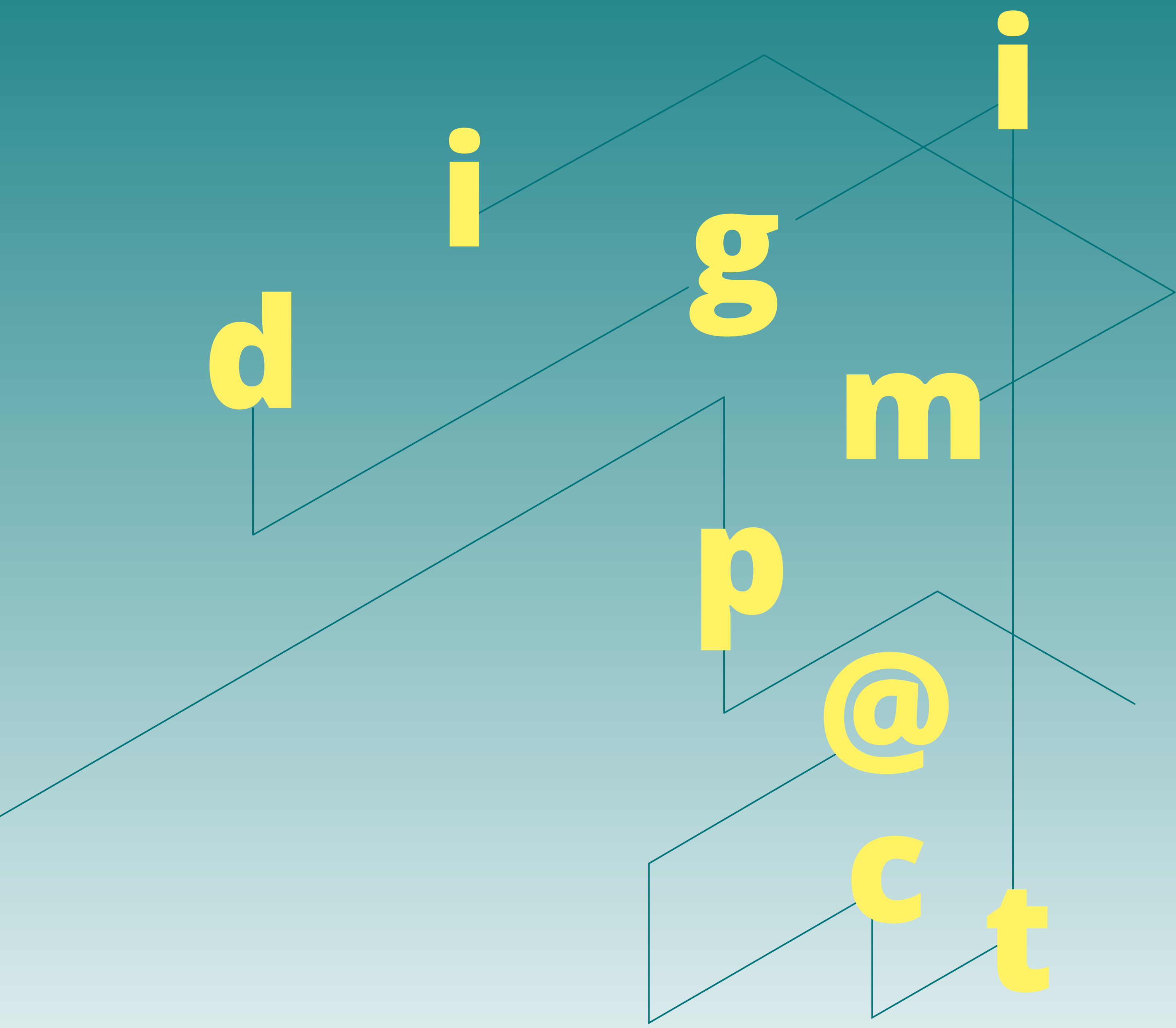

GAME INDUSTRY DECARBONIZATION.

How to ease and fasten its pace for game studios, the entire industry, and the end-users?

This report was

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SUMMARY

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Abstract

"Game development is the core of the game industry decarbonization."

In the context of :
— Achieving carbon neutrality to limit the magnitude of climate change;
— The energy crisis.

The gaming industry has begun its decarbonisation with since 2019 a global structuring initiative, the Playing for the Planet Alliance (UNCC), which voluntarily commits its members to calculating their carbon footprint, then to setting a decarbonization target in line with the carbon neutrality trajectory (Paris agreements) and finally to deploying an action plan to achieve it.

The decarbonization trajectory for the ICT sector (which include the game industry) is based on the International Telecommunication Union's ITU-T L.1470 recommendation to reduce GHG emissions by 45% between 2015 and 2030, which has been validated by the Science Based Target Initiative (SBTI).

The destination is clear, but the journey is uncertain, as assessing the ICT footprint is difficult due to methodological grey areas and the lack of consolidated activity data especially for hardware and cloud services.

Nevertheless, the first carbon footprints of major industry players such as Ubisoft are beginning to appear. While useful for improving understanding of the sector's GHG emissions, these company (studio) oriented footprints are not granular enough to assess the specific carbon footprint of projects (game development), whose footprint is "lost" in that of the company (studio).

This makes it exceedingly difficult to decarbonise game development due to the lack of its emissions data, whereas decarbonising development i.e., act on the game size and energy efficiency has repercussions on the entire value chain: distribution, end-using, and is becoming increasingly critical with the spread of cloud gaming.

At present, the game industry advocates a range of reduction levers, but these are insufficiently classified, documented, and quantitatively evaluated.

It is therefore necessary to resorb these bottlenecks that impacts on the whole industry and end-users through a rational approach.

To achieve this, we prescribe the constitution of a pilot working group of game studios including the ten main development-related professions, mentored by environmental and digital responsibility experts, and coordinated by neutral institutions: Pulse & VAF.

The expected results are:

1. Game development data consolidation i.e., provide real-world data through :
    — simplify and harmonize activity data collection;
    — improve emissions allocations to pipeline steps i.e., art, design, development, production marketing-during the work in progress i.e., pre-production, production, post-production, Q.A, release;
    — identify the allocation keys for the support function e.g., human resources, and the cloud services;
    — measure the GHG emissions of a game development from multiple kind of games;
    — shape missing emissions factors per steps/task e.g., Design/GDD (game design document);
    — assess clean code leverage effect on GHG emissions reduction (if possible).
2. A sustainable design framework, by game development steps and tasks, categories e.g., animation, DevOps, programming... or key roles e.g., designer, developer, 3D artist...
3. Support for the dissemination of the working group results at national level and implementation of collective and individual training courses on a voluntary base.

This bottom-up approach will advance knowledge, thus making an important contribution to the effective decarbonisation of industry, with a structuring effect on the entire Flemish and European game industry ecosystem.

Preamble

Which Flemish institutions facilitated this report?

— Pulsenetwerk[1]
A bottom-up network that was founded by several players in the cultural scene in Flanders, who were on the forefront of sustainability in arts, culture, media, and youth.

Pulse – Cultural Network for Transition believes that culture can be a driver for transition to a socially just and sustainable society. It connects cultural organizations that experiment with sustainable alternatives to our current societal model, with self-sufficiency and cultural activism at its core.

— Flanders Audiovisual Fund (VAF)[2].
The VAF is a public funding body that supports audiovisual and games production in, and international co-productions with Flanders.

What is the main target of this report?

— The Flemish game studios (developers) who are or will be stakeholder of the low-carb transition.
— Game studios in Europe.

What is the focus and the scope of this report?

— Within the lifecycle of the game industry, our aim is to provide methodology and operational guidelines for the decarbonation of game development' pipeline i.e., Game Content Design and Development.

1 Pulse Transitienetwerk, 2022.
2 Flanders Audiovisual Fund (VAF), 2022

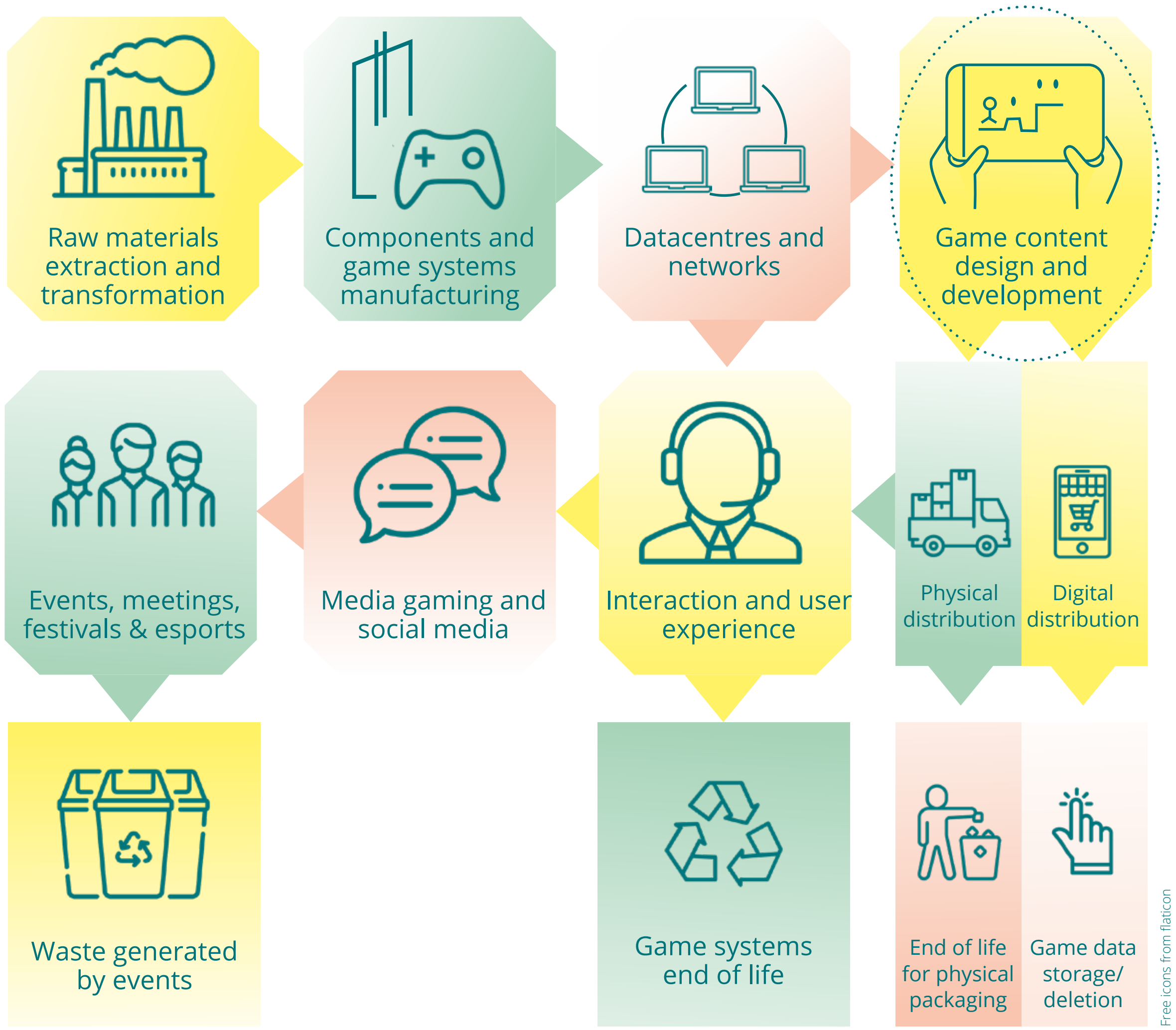

Figure 1. *Game industry lifecycle-step addressed in this report. Reference: Green Game Guide.*

— This report is also a specification for the structuring of a working group assembling a consortium of game studios.

Introduction

The global warming must be addressed, thanks to a trajectory of greenhouse gas (GHG) emissions abatement.

Company GHG emissions like game studios are allocated into three different scopes:
— scope 1, which covers direct emissions emanating from the company's own assets;
— scope 2, which covers emissions related to purchased energy;
— scope 3, which covers remaining value chain emissions over which the company has some influence.

The mandatory GHG emissions reduction is to achieve carbon neutrality by 2050, i.e., total GHG emissions = total absorption capacity of natural carbon sinks (soils, ocean, forests, meadows).

In 2022, the world is far from being aligned with this trajectory, as shown in the figure below, which compares three scenarios corresponding respectively to the policies in place (STEPS), the commitments notified under the Paris Agreement to reach carbon neutrality (APS)[3] and the efforts required to achieve NET Zero in 2050 (NZE).

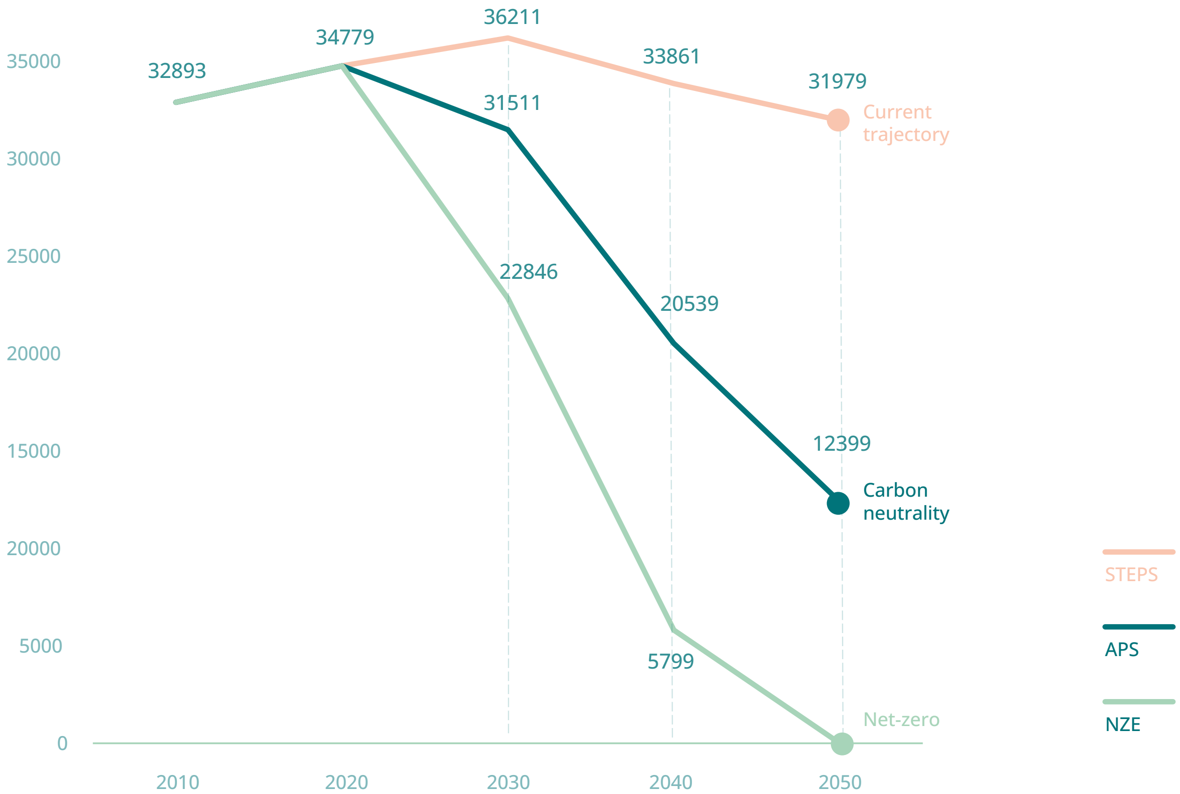

Figure 2. *Three scenarios of global emissions evolution in millions of tons of CO2e.World Energy Outlook 2022-IEA[4].*

3 What is the Paris Agreement? – United Nations Climate Change, 2015.
4 World Energy Outlook 2022 dataset – International Energy Agency (IEA), 2022.

There is a widespread confusion about the GHG emissions reduction needed to achieve Net Zero emissions (NZE), with the most common belief being that it will be achieved by following the Paris Agreement (APS) trajectory (carbon neutrality).

Carbon neutrality (APS) is a key step towards achieving Net Zero. It allows a balance to be struck between global anthropogenic CO2 emissions and their absorption. Indeed, the CO2 impact is counterbalanced by carbon offsetting (i.e., financing projects to reduce GHG emissions). Only once carbon neutrality has been achieved can companies choose to go further and aim for Net Zero. To do this, organisations must reduce the amount of GHGs emitted by their operations as much as possible.

Notwithstanding this light confusion, the transition to carbon neutrality (APS) will have powerful effects on the economy and even more for Net Zero.

The three mechanisms it is bound to mobilise – substitution of capital for fossil fuels, reorientation of technical progress and the search for greater sobriety in lifestyles – will all have marked repercussions on production, consumption, investment, foreign trade, employment, inflation, public finances, and inequalities.

In the long term, i.e., ten or twenty years from now, building a climate-neutral economy is likely to be easier than was recently thought. Of course, the problems are far from being solved. But if efforts need to be accelerated, it is not only because the consequences of inaction are proving to be more hurtful than anticipated e.g., an increase in extreme weather events. It is also because it is reasonable to believe that the goal is within reach.

For the time being, however, we must not hide from the difficulties. Pretending, as has been done too often, that the transition will be painless is neither convincing nor mobilising. By its very nature, it requires efforts, and it involves costs.

This challenge is not out of reach, but it is critical to understand what is at stake.

By sector of activity, an explicit, economically rational, and credible strategy, shared collectively, will make it possible to limit the costs of this transition and to perpetuate the activity.

Beyond decarbonisation other environmental impacts needs to be mitigated e.g., abiotic resources scarcity, biodiversity loss, air & water pollution …

In the context of the game industry transition, remarkable decarbonisation initiatives surges:
— Playing for the Planet Alliance (P4P)[5]
— Green Games Guide[6]
— Game Umwelt-Guide[7]
— Climate Handbook for Game Companies[8]

5 Annual Impact Report – Playing for the Planet Alliance (P4P)-2022.
6 Green Games Guide – UKIE, Games London, 2021.
7 Game Umwelt-Guide – The German Game Industry Association,2021.
8 Climate Handbook for Game Companies – Play Create Green,2022.

Main initiatives (4)	Description	Interest for game studios
Playing for the Planet Alliance (P4P) and its yearly reports-2019	The P4P Alliance was launched during the Climate Summit at UN Headquarters. Members have made commitments ranging from integrating green activations in games and reducing their emissions.	The P4P present in a yearly report what are the best practices the video game industry can take. Solutions for studios by major emission item: transportation, energy, waste...
Green Games Guide-2021	The Green Games Guide is the UK's first resource that contains practical advice and outlines steps that games business can take to reduce emissions and waste across their offices and operations.	Case study: carbon footprint of playing games Guidelines for carbon accounting and offsetting Solutions for studios by major emission item: transportation, energy, waste...
Game Umwelt-Guide-2021	Sustainability initiatives from the German game industry.	Tips for a climate-neutral company
Climate Handbook for Game Companies	An evolving climate handbook by and for game companies. A knowledge sharing community with active climate ambassadors.	Case and action-based tool Best practices highlight updated frequently Platform to gather a community Tools like LCA models, roadmaps, guidelines • a collection of new research and findings

Table 1. *Main current references for the low-carbon transition of the game industry.*

These resources are focused on carbon accounting and sustainability implementation into the studios and the games (sensitization). They are valuable to initiate the transition, however in the perspective of the carbon neutrality (APS), we should go further, notably on the game content design and development part (please see figure 1).

Hence, this report ambition is to set the next step in sustainability embodiment of game studios framework i.e., take in account the specific GHG emissions of the game content design and development through studio' pipeline.

This is the prerequisite for a granular game studios decarbonisation, **indeed the carbon footprint of game development is currently "lost" in the overall studio' footprint**, so there is no carbon emissions visibility for game development, please see figure below.

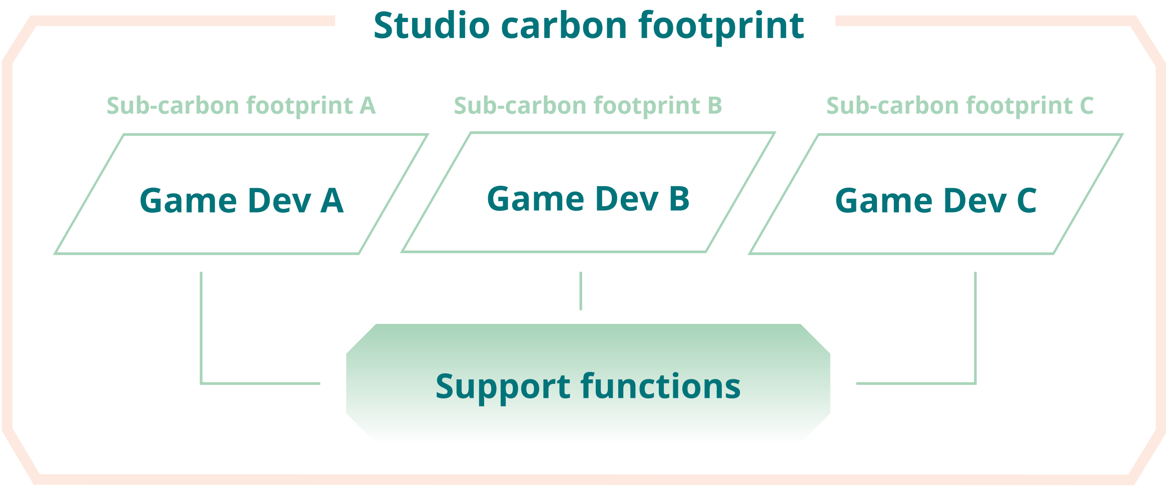

Figure 3. *The carbon footprint of game development is not isolated.*

This is an area where knowledge can progress to enable finer decarbonisation and optimisation.

To address this stake, we envision the Game industry decarbonation state of the art, notably its recommended GHG emissions trajectory and the current limitations to go further.

Then, we provide an overview of the prescribed decarbonization levers and their solutions.

Eventually, to overcome the decarbonization current limitations, we shape a resolute decarbonization approach for game development i.e., data consolidation / measurement of game studios' pipeline, and we lay the foundations of what could be a sustainable design framework for game development.

1 — Game industry decarbonization

In this chapter, we will look at the climate impact of the whole Information and Communication Industry (ICT) as it relates to video games and the decarbonisation trajectory it must follow. We will then study the industry's decarbonisation commitments and the carbon footprint of two studios.

Finally, we will look at the latest advances in the field of decarbonisation.

1.1 — ICT impacts : carbon footprint and E-waste

What is the current and projected main impacts of ICT? The ICT's main impacts are energy consumption, GHG emissions and e-waste generation

1.1.1 — ICT CURRENT IMPACTS

The ICT sector is divided into the three main sub-sectors: end user goods (user devices); networks (including both mobile and fixed); and data centres, including enterprise networks.

A large share of the GHG emissions come from entertainment and media (E&M) companies, including game industry companies.

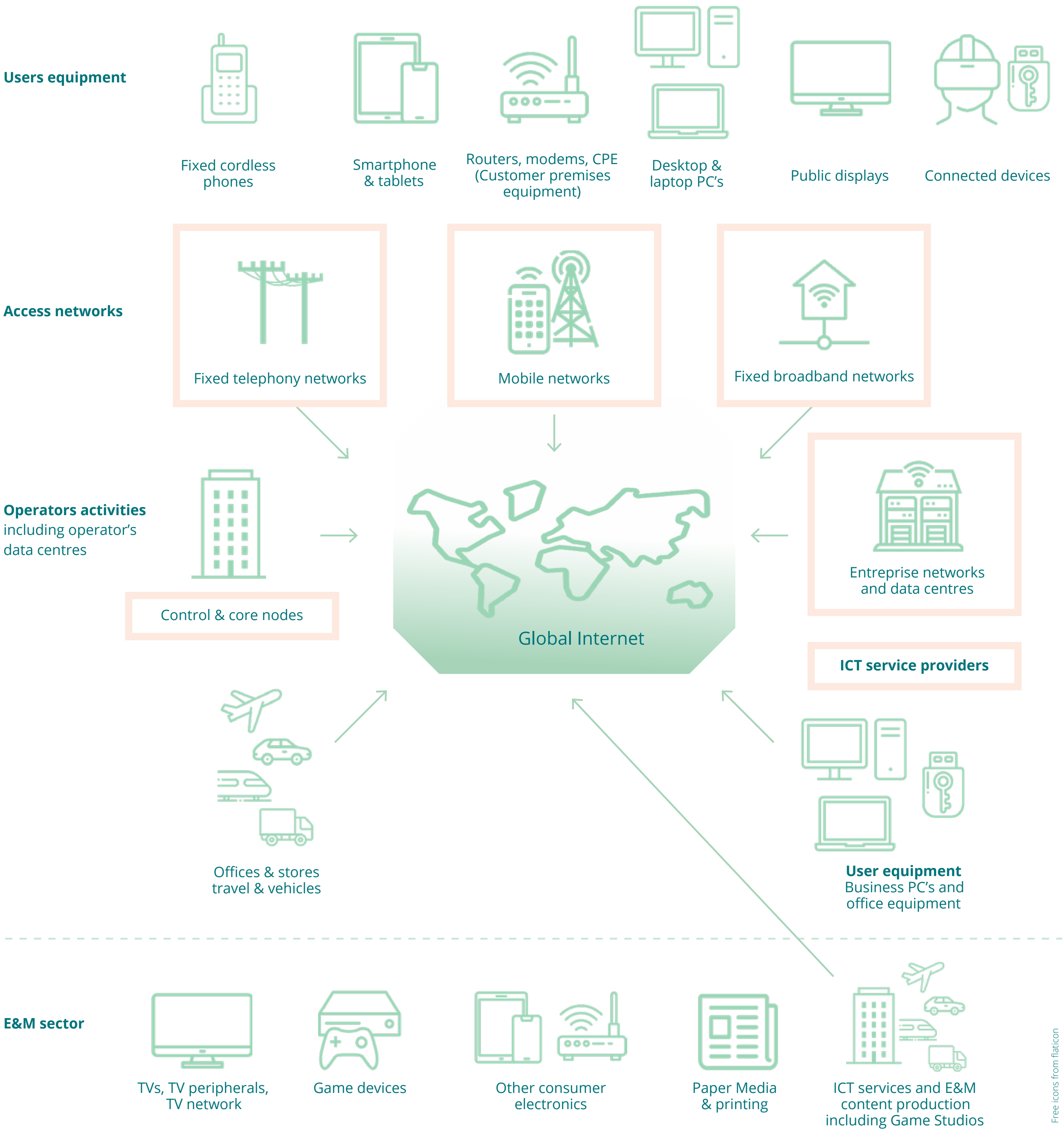

Figure 4. *ICT sector overview. Revamped from International Telecommunication Union (ITU).*

ICT sector is estimated at ca. 1.8–2.8% of global GHG emissions in 2020[9]. Estimates of ICT's emissions in 2020 vary between 0.8 and 2.3 GtCO2e, there are uncertainties, but it gives a reasonable approximation of the ICT' GHG impact.

The individual GHG emissions contribution in % of each category of devices in 2020 was as follows[10].

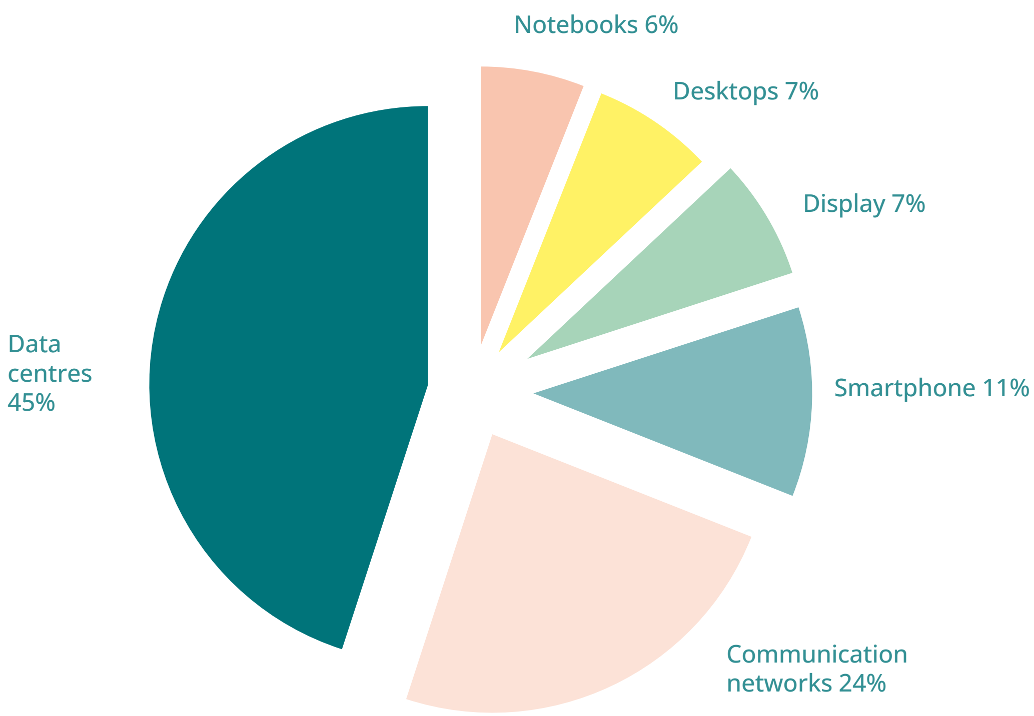

Figure 5. *Relative GHG emissions contribution of each ICT category in 2020- Belkhir & al, 2018.*

Data centres and communications networks alone accounted for 69% of the ICT carbon footprint in 2020.

Another source, the latest energy data[11] and analysis from the International Energy Agency (IEA) demonstrates an exponential growth demand for digital services between 2015 and 2021. Please see following table.

9 The real climate and transformative impact of ICT: A critique of estimates, trends and regulations – Charlotte Freitag & al, 2021

10 Assessing ICT global emissions footprint: Trends to 2040 & recommendations – Belkhir & al, 2018.

11 Data Centres and Data Transmission Networks – IEA, 2022.

Items (6)	2015	2021	Change
Internet users	3 billion	4,9 billion	+60%
Internet traffic	0,6 ZB	3,4 ZB	+440%
Data centre workloads	180 million	650 million	+260%
Data centre energy use (excluding crypto)	200 TWh	220-320 TWh	+10-60%
Crypto mining energy use	4 TWh	100-140 TWh	+2300-3300%
Data transmission network energy use	220 TWh	260-340 TWh	+20-60%

Table 2. *Global trends in digital and energy indicators, 2015-2021.*
Sources: Internet users [ITU (2022)]; internet traffic [IEA analysis based on Cisco (2015); TeleGeography (2022); Cisco (2019), Cisco Visual Networking Index]; data centre workloads [Cisco (2018), Cisco Global Cloud Index]; data centre energy use [IEA analysis based on Malmodin & Lundén (2018); ITU (2020); Masanet et al. (2020); Malmodin (2020); Hintemann & Hinterholzer (2022)]; cryptocurrency mining energy use [IEA analysis based on Cambridge Centre for Alternative Finance (2022); Gallersdörfer, Klaaßen and Stoll (2020); McDonald (2022)]; data transmission network energy use [Malmodin & Lundén (2018); Malmodin (2020); ITU (2020); Coroama (2021); GSMA (2022)].

Since 2015, the number of internet users worldwide grew by 60%, while global internet traffic has expanded by 440%. Rapid improvements in energy efficiency have, however, contributed moderate growth in energy demand from data centres and data transmission networks, which each account for 1 to 1.5% of global electricity use.

In addition to their operational energy use and emissions, data centres and data transmission networks are also responsible for “embodied” life cycle emissions (upstream and downstream scope), including from raw material extraction, manufacturing, transport, and end-of-life.

Robust growth in demand for data network services will keep-up, driven by data-intensive uses such as cloud gaming, augmented and virtual reality applications plus video streaming. However, these data-intensive services may only have limited impacts on energy use in the near term since energy use does not increase proportionally with traffic volumes[12].

Beyond the energy use and GHG emissions, data centres and data transmission networks also pose other environmental impacts such as soil artificialization, water use and the generation of electronic waste.

Matching growth in ICT networks and services, latest estimates from Global E-Waste (UN) show that the world now discards 53.6 million Mt of e-waste per year[13] – only 17.4% is formally collected and recycled. In 2019, the fate of 44.3 Mt of generated e-waste was unknown – this waste was either not documented, being discarded in landfill, burned, or illegally traded .

In Belgium, the e-waste generated amount to 20,4 kg per capita[14], whom 11,2 kg are formally collected (50%), which is far superior to the average recycling rate (17,4%).

12 Does not compute: Avoiding pitfalls assessing the Internet’s energy and carbon impacts – Koomey & al, 2021.
13 The Global E-waste Monitor 2020 – Quantities, flows, and the circular economy potential – Sustainable Cycles (SCYCLE) programme-United Nations,2022.
14 Map the global E-waste – Sustainable Cycles (SCYCLE) programme-United Nations,2022.

In the long-term, according to the IEA, significant additional efforts on energy efficiency, RD&D, and decarbonising electricity supply and supply chains are necessary to curb energy demand and reduce emissions rapidly over the coming decade to align with the Net Zero by 2050 Scenario.

According to a broad agreement by analysts in the field on certain key assumptions[9].

— The world's carbon footprint needs to decrease to avoid climate catastrophe;
— Data traffic is continuing to grow fuelled by rising activities such as Cloud gaming;
— Energy demand by ICT is increasing;
— Demand for data centres and network services will increase;
— The shift to smartphones is decreasing emissions from PCs and TVs;
— Using more renewable energy would reduce ICT emissions;
— ICT could reduce emissions in other sectors but not by default and only under certain conditions;
— ICT has the potential to increase its own emissions and facilitate rising emissions in other sectors.

Opinions are more divided regarding future trends in emissions.

1.1.2 — ICT PROJECTED IMPACTS

Among research papers, ICT's GHG emissions could be 2.1%–3.9% to 14% (business as usual – maximum exponential) by 2040[15]. Please see the figure below.

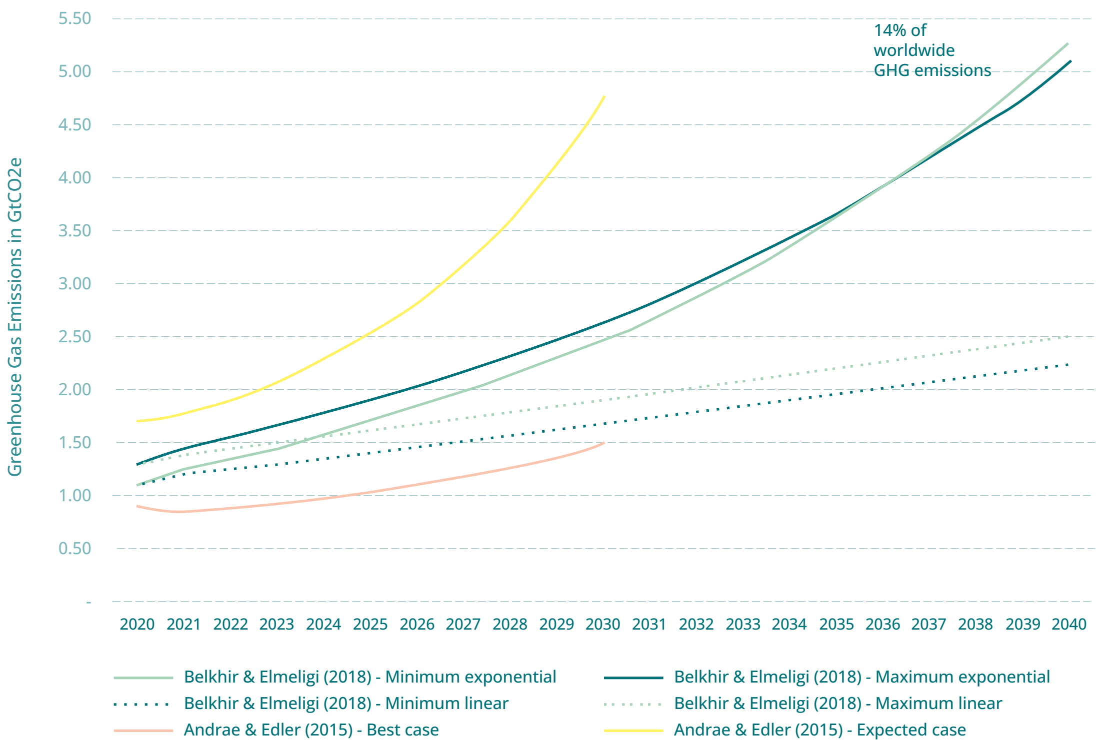

Figure 6. *Projections of ICT's GHG emissions from 2020 to 2040.Projections review by Freitag & al (2020).*

15 The climate impact of ICT: A review of estimates, trends and regulations – Freitag & al, 2020.

It is impossible to judge which study makes the most reliable predictions about ICT's future emissions based on methodology alone as the variability of data and the lack of coherent standards for carbon accounting leads to different approaches, scopes and assumptions being used by different studies.

"Carbon accounting is an imprecise science due to the complexity of the supply chain emissions pathways and issues with how to allocate emissions to a particular product, activity, or sector. For each carbon footprint calculation, there is a margin of error.

The uncertainty increases even further for projections of future emissions, as these are influenced by the actions of companies, policy makers, individual users and unforeseen events like natural catastrophe and pandemics.

There are unknowns including what changes future innovations might bring or the carbon footprint of activities which are undocumented (e.g., the dark web). The carbon footprint of some of the emerging ICT trends such as the metaverse are also difficult to calculate." – Freitag & al, 2020[15].

Anyway, there are reasons to think, that ICT's GHG emissions are under-estimated and that they are going to increase due to rebound effect, the omission of growth trends in ICT such as XR and Cloud Gaming …and significant investment in developing and increasing uptake of Blockchain, AI and IoT…

> *"Truly persistent and immersive computing, at scale and accessible by billions of humans in real time, will require even more: a 1,000-times increase in computational efficiency from today's state of the art".*
>
> *Raja Koduri, Intel Senior vice president, General manager of the Accelerated Computing Systems and Graphics Group,2021*[16].

On the digital waste side, with a linear growth of ICT, the amount of e-waste will double by 2050[17].

In summary, ICT' GHG emissions will increase significantly, although the magnitude of this increase remains to be seen. Beyond the environmental impact, this raises a concern of accuracy and harmonisation of ICT carbon accounting.

What is the GHG emissions ICT trajectory including game industry for 2030?

16 Powering the Metaverse – Intel, 2021.
17 Future e-waste scenarios – UN environment, 2022.

1.2 — Relevant ICT (including game industry) GHG emissions trajectory for 2030

The ICT sector must reduce its GHG emissions at a rate on par with the global economy.

A new ITU standard highlights that compliance with the Paris Agreement (carbon neutrality) will require the information and communication technology (ICT) industry to reduce greenhouse gas (GHG) emissions by 45 per cent from 2020 to 2030, i.e., a reduction of 3 per cent/year

All companies, along the ICT value chain including game studios must do their part to increase system-wide efficiency, including hardware manufacturers, software developers such as the game studios and customers.

The baseline year for the ICT sector decarbonization trajectory is set to 2015 (0,75 GtCO2e). With a 2020 carbon footprint of 0.8 and 2.3 GtCO2e, the decarbonisation process is already late on the trajectory schedule.

It is the recommendation ITU-T L.1470 (01/2020)[18] that provides detailed trajectories of greenhouse gas (GHG) emissions for the global information and communication technology (ICT) sector and sub-sectors that are quantified for the year 2015 and estimated for 2020, 2025 and 2030. In addition, Recommendation ITU-T L.1470 establishes a long-term ambition for 2050.

This recommendation has also some related supplement e.g.,

— L Suppl. 44 (05/2021)-Guidelines on best practices and environment friendly policies for effective information and communication technology deployment methods;
— L Suppl. 47 (07/2022)-Examples of resource saving within the information and communication technology sector;
— L Suppl. 49 (07/2022)-Overview on adaptation to climate change for information and communication technology networks;
— L Suppl. 52 (10/2022)-Computer processing, data management and energy perspective;
— L Suppl. 53 (10/2022)-Guidelines on the Implementation of environmental efficiency Criteria for AI and Other Emerging Technologies Guidelines on the Implementation of environmental efficiency Criteria for AI and Other Emerging Technologies...

The recommendation identifies the GHG emissions from organizations (suppliers, manufacturers, operators) and consumers (end-users).

A game studio is considered as an ICT supplier, by convention it must account its emissions in the following way.

18 ITU-T L.1470 – International Telecommunication Union (ITU), 2020.

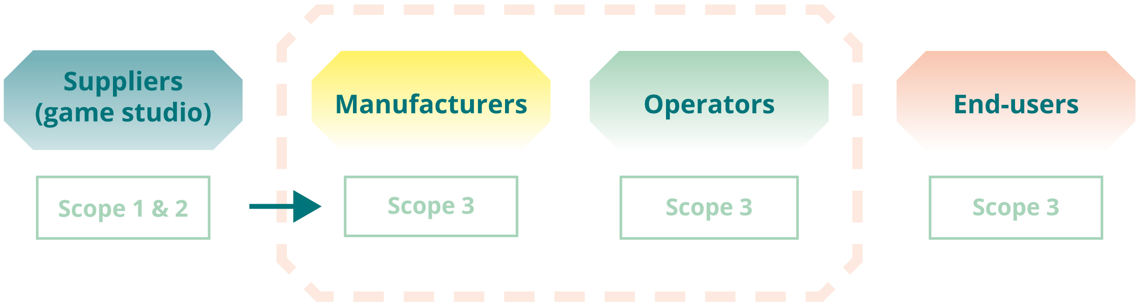

Figure 7. *Game studios (suppliers)-GHG emissions scope accounting along the ICT value chain.*

In a game studio perspective, GHG emissions related to its equipment from manufacturers, its hosting services from operators and the use of its game by end-users must be accounted within scope 3 (indirect emissions) i.e., game studios' GHG emission are spread in the whole ICT value chain.

The recommended emission-reduction target (-45%) is the first targets specific to the ICT industry to be approved by the Science Based Target Initiative (SBTi)[19]. We must stress that this ICT carbon neutrality trajectory is modelled on the Paris Agreement (APS), it will not be enough to reach Net Zero (NZE), please see figure 2.

Moreover, a study by Lancaster University in UK[20] estimated that if gamers moved to streaming (cloud gaming) by 2030, GHG emissions could increase by 30% to 112% depending on the uptake range. And that is before considering streaming in higher resolutions i.e., 4k instead of 1080p. In fact, there is a persistent rumour in the industry that consoles will soon be replaced by streaming.

Nevertheless, pioneering game studios have already initiated their decarbonisation trajectory by accounting their GHG emissions and targets settings.

19 Guidance for ICT companies setting Science Based Targets – Science Based Targets Initiative, 2021.
20 From One Edge to the Other: Exploring Gaming's Rising Presence on the Network – Marsden & al 2020.

1.3 — Decarbonization case: Ubisoft

The decarbonisation process is as follows:

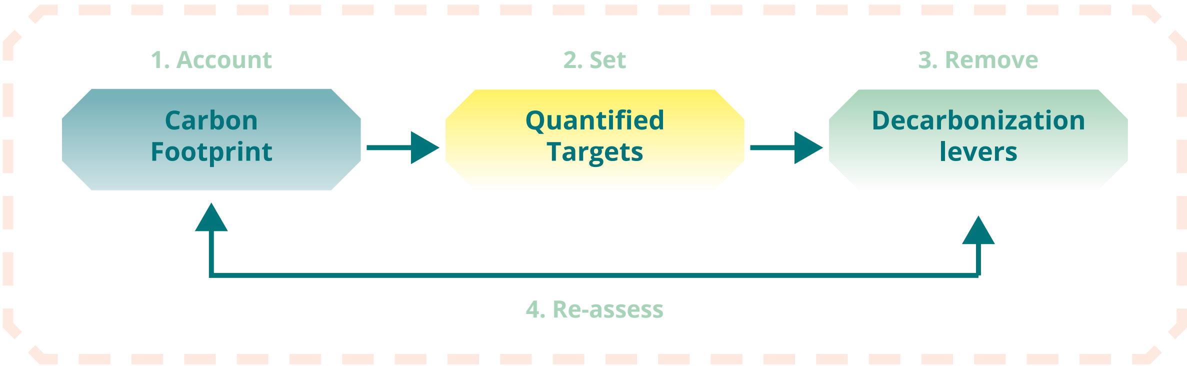

Figure 8. *Game studio's decarbonization action plan.*

It is an iterative process, which requires periodic reassessment to check that the targets are being met and that the decarbonisation levers are effective and do not lead to a rebound effect.

In this section we present the decarbonization approach of Ubisoft, the renowned studio and publisher is a member of the P4P initiative[5], and of Science Based Targets Initiative[21].
In September 2020, Ubisoft implemented a long-term commitment to global carbon neutrality called Play Green[22], which is their decarbonization action plan.

1.3.1 — UBISOFT CARBON FOOTPRINT

Ubisoft's carbon footprint in 2021 was 141.700 tons CO2e[23]. This number includes scope 1, 2, and 3 upstream emissions, covering all direct and indirect emissions necessary to Ubisoft' operations, from upstream emissions from their suppliers to downstream emissions stemming from the distribution of their products to physical retailers and digital platforms.

Please see following figure.

21 Companies taking action – Science Based Targets Initiative, 2022.
22 Play Green: Ubisoft's Commitment to Global Carbon Neutrality – Ubisoft, 2020.
23 2021 carbon footprint by category – Ubisoft, 2021.

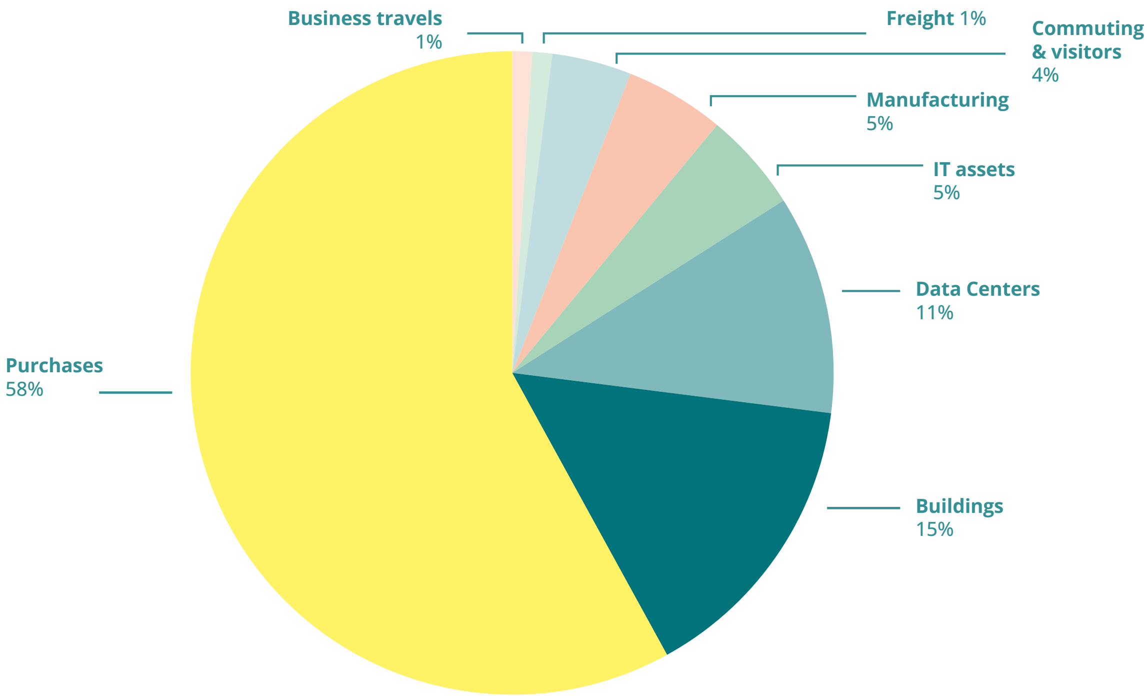

Figure 9. *Ubisoft' carbon footprint by category.*
"Carbon dioxide equivalent" (CO2e) measures the global warming potential of a mixture of greenhouse gases. It represents the quantity of CO2 that would have the same impact on global warming as the mix of interest and is used as a standardised unit to assess the environmental impact of human activities.

The majority of GHG emissions are from scope 3 upstream (purchases of goods & services). Emissions from freight and air travel are negligible.

To be in line with the recommended ICT decarbonation trajectory and if the company follow Emissions from freight and air travel are negligible. a decarbonation in absolute terms (and not in relative terms indexed on its turn-over/market share), by 2030 Ubisoft should reduce its GHG emissions by 27%, i.e., minus 38.259 tCO2e.

In 2020, the average Belgian emits 9.5 tCO2e/year[24], thus Ubisoft's required reduction represents the cumulative footprint of 4,027 Belgians.

Following the completion of its carbon footprint, Ubisoft has set reduction targets.

24 Greenhouse gas emissions per capita, Belgium – Eurostat, 2020.

1.3.2 — UBISOFT' DECARBONIZATION TARGETS

Their climate commitment is a reduction target per employee based on 2019 levels (which were of 9.5 tCO_2e per employee) for:

- 2023, it is - 8,8%[22]
- 2024, it is -10,8%[22].

This commitment is slightly below the recommendation's target of 12% decarbonisation by 2024 to, we can consider that this commitment is formulated in relative terms.

Ubisoft is also working on a carbon footprint reduction plan for 2030, which will be submitted to the Science-Based Targets initiative for validation[21], in line with the goal of limiting global warming to 1.5°C, to reach carbon neutrality.

To achieve this, Ubisoft will deploy a range of decarbonisation levers.

1.3.3 — UBISOFT'S DECARBONIZATION LEVERS AND THEIR SOLUTIONS MIX

Play Green[22] intend to act on two key priorities:

- Inspire team members, partners, and players

Raising awareness among their stakeholders and encouraging positive action for the climate and the environment;

- Reduce the company's carbon footprint

Decarbonizing Ubisoft direct operations on 4 levers: transition to renewable energy, efficiency, self-restraint (sobriety), shift to low-carbon alternatives (including circular economy), please see the following table.

Levers by scope	Description	Solutions mix
Renewable energy-Scope 1,2	Transition to electricity from renewable sources.	– Reach 100% electricity from renewable sources (vs. 74% in 2020).
Efficiency-Scope 1,2	Review and redesign processes and operations to reduce related emissions	– Ensure environmentally sustainable teleworking processes and systems. – Optimize the power consumption of the buildings (heating, air conditioning, lighting, computer equipment). – Engage our data centres in an environmental management program and investigate ways to reuse the heat and liquid cooling of our servers.

Levers by scope	Description	Solutions mix
Sobriety-Scope 1,2,3	Improve behaviours and habits to be more sustainable.	– Maintain a low level of international business travel by continuously developing better remote collaboration tools.
Low-carbon alternatives-Scope 3	Shift to low-carb solutions and circular economy scheme implementation	– Aim to eliminate single-use plastics and reduce overall waste while optimizing sorting in all the workspaces. – Update the procurement policy and motivate the suppliers to decarbonize their products and services. – Improve the management policy for IT hardware by extending the average lifecycle of our top assets and giving a second life to hardware (through reuse, recycling and/or donations). – Continue to digitize the distribution of our games to limit material waste and carbon impacts.

Table 3. *Ubisoft decarbonization levers and their solutions.*

These levers embodied in operational solutions are consistent and extensive. It should be noted, however, that a large part of the emissions reduction will depend on suppliers (which account for 58% of GHG emissions): data centre operators, service and products suppliers and subcontractors.

Ubisoft has the market power to impose these external decarbonisation efforts on its suppliers. On the other hand, smaller game studios like the Flemish ones will not be able to put pressure on their suppliers, such as operators, so they will have to favour internal decarbonisation.

Ubisoft is strongly involved on the GHG issue, its rational approach is an example to the industry. We can hope that it will inspire game companies (publisher & studios) to deliver physical decarbonisation on the climate challenge scale.

Other studios and publishers have made climate/environmental commitments.

1.4 — Climate/environmental commitments from the P4P members.

Under the umbrella of the P4P initiative[4], its members have made ambitious and time-based climate/environmental commitments[25], over 60% of the 43 alliance members (developers, publishers, trade-bodies, associations, graphic engine, retail distributor & platforms) have made a commitment to become carbon neutral or even Net Zero by 2030.

In addition to reducing GHG emissions, the commitments cover corporate social responsibility (CSR) issues such as gender metrics: the percentage of women working in leadership positions or are part of the company board.

The commitments are articulated between general commitments that are binding on all members and the voluntary specific commitments of each member, this creates collaboration and emulation between members.

The P4P alliance's annual report assesses the achievement of general and specific commitments, this strengthens the legitimacy of the alliance and its expected results.

1.4.1 — P4P: GENERIC COMMITMENTS ANALYSIS

They are issued in a common baseline logic (still quite ambitious), they serve as general guidelines, a framework for action for the members:

— Corporate carbon footprint reductions and a collective shift to green energy (from renewables).

This is a goal on which there is scientific, technical, and economic consensus.

— Insertion of green nudges into games.

Green nudges are a promising new tool to encourage consumers to act in an environmentally benign way, such as choosing renewable energy sources or saving energy. However, there are some drawbacks[26]:
— many green nudges seem limited with respect to their behavioural effectiveness;
— green nudges should, as a rule, be seen as complements to, rather than substitutes for, traditional incentive-based measures;
— green nudges must be organized in a transparent to make green nudges ethical.

Green nudges are an interesting tool to insert into the gameplay of games, but it must be properly contextualised and transparent.

25 Members and commitments – Playing for the Planet alliance, 2022.
26 Green nudges: Do they work? Are they ethical? – Christian Schubert, 2016.

— Commitments to offset emissions (for internal operations and gamer's devices).

Carbon offsetting is a must have in the decarbonization toolbox, it is a flexible way to compensate for carbon footprint for example by sponsoring fuel-efficient stoves in developing countries, reduction in deforestation or hydroelectric and wind-based power plants[27].

Trees play a significant role in carbon sequestration and although not all GHGs emitted could be sequestered, CO_2 represents 74.4% of these emissions[28].

The amount of CO_2 sequestered by a tree per unit of time depends on factors, such as its species, size, or environment.

A study conducted by Lefebvre & al., 2021 shows that each tree planting in low altitude tropical rainforest can reach 100 kg CO_2 captured per tree (4.1 years after planting)[29], it is a slow absorption process and trees must not be cut down for at least a century to sequester carbon sustainably.

As a result, carbon offsetting cannot be the main lever of action to scale the GHG emissions reduction, moreover, it may discourage the willingness to reduce decisions within the industry's value chain.

Carbon offsetting should be used primarily to reduce residual emissions (which cannot be reduced otherwise).

For the moment it is the most used lever because it is one of the easiest to deploy.

— New circular economic design and recycling offerings to control plastic and e-waste

This is a goal on which there is scientific, technical, and economic consensus.

There is a natural substitution between plastic waste and e-waste with, on the one hand, the dematerialisation of games thanks to the distribution of games by platforms with digital rights management e.g., Steam and, on the other hand, the rise of Cloud gaming which reduce the consumption of plastic to build consoles.

Each P4P member is also encouraged to set specific targets.

27 United Nations Carbon Offset Platform – UNCC, 2022.
28 Greenhouse gas emissions – Our World in Data, 2022.
29 Assessing the carbon capture potential of a reforestation project – Nature, Lefebvre and al, 2021.

1.4.2 — P4P: GAME STUDIOS SPECIFIC COMMITMENTS

We focus on the climate/environmental commitments of P4P Alliance' game studios[25] (developers) to inspire Flemish ones.

The game studios (developers) are the bulk part of the P4P Alliance members: 26/43, i.e., 60,5%. Please see their climate-related commitment[25] in the following table.

Game studios (developers)-26	Climate-related commitment	Quantified and time-based decarbonization target set? Year of reference 2022
37 Interactive Entertainment[30]	Offset 60% of the company's carbon emission by using green electricity in 2021 and reach carbon neutrality before 2025.	Yes
Bandai Namco[31]	All group companies must strive to reduce carbon emissions by 35% by the year 2030 and be carbon net-zero by 2050.	Yes
Creative Assembly[32]	Carbon emissions data collection at CA by 2022	No
Creative Mobile[33]	Promoting environmentally conscious choices and lifestyles across its gaming products	No
Dropledge[34]	Reduce carbon footprint by 30% by 2022.	Yes
E-Line Media[35]	Explore how gaming design / technology can look into the future and present visions of sustainable futures.	No
Future Games of London (Ubisoft studio)[36]	Complete a carbon footprint assessment of the studio and their games.	No
Gameloft[37]	Reach a carbon neutral footprint (not time-based commitment).	No
Internet of Elephants[38]	Creating games for wildlife conservation using real scientific data	No

30 37 Interactive Entertainment, 2022.
31 Bandai Namco, Europe, 2022.
32 Creative Assembly, 2022.
33 Creative Mobile, 2022.
34 Dropledge, 2022.
35 E-Line Media, 2022.
36 Future Games of London (Ubisoft studio), 2022.
37 Gameloft, 2022.
38 Internet of Elephants, 2022.

Game studios (developers)-26	Climate-related commitment	Quantified and time-based decarbonization target set? Year of reference 2022
Mag Interactive[39]	Have a zero-carbon footprint as a company through offsetting their impact as well as be thoughtful regarding how they use resources in their business.	No
Niantic Inc[40]	Engage 100,000 players to partake in sustainability efforts.	No
Pixel Federation[41]	Map out their carbon footprint and reduce it by 5% in 2022 and achieve net-zero emissions by 2030.	Yes
Reliance Games[42]	Calculate and make reasonable attempts to reduce/minimize their carbon footprint.	No
Rovio[43]	Offset the carbon emissions generated by Rovio games' daily active users each charging one top-end mobile device once per day.	No
Sega[44]	Committed to reducing its own carbon footprint following an internal audit	No
Sybo[45]	Offset more than double their office carbon footprint, yearly offsetting 200 tonnage of CO2.	No
Space Ape[46]	Reduce carbon footprint by 10% in 2020 Offset 200% carbon footprint 2018 onwards as well as the carbon footprint created by playing their games.	Yes
Sports Interactive[47]	Replace their plastic games box with a recycled cardboard sleeve to save 20 tonnes of plastic.	No
Strange Loop Games[48]	Aim to create experiences that better equip players to face global challenges	No

39 Mag Interactive, 2022.
40 Niantic Inc, 2022.
41 Pixel Federation, 2022.
42 Reliance Games, 2022.
43 Rovio, 2022.
44 Sega, 2022.
45 Sybo, 2022.
46 Space Ape, 2022.
47 Sports Interactive, 2022.
48 Strange Loop Games, 2022.

Game studios (developers)-26	Climate-related commitment	Quantified and time-based decarbonization target set? Year of reference 2022
Sumo Group[49]	Become Carbon Net Zero across the whole of Sumo Group Worldwide by 2025 via a combination of: 1) investment in efficient facilities and equipment and 2) behavioural change initiatives and purchasing carbon offsets.	Yes
Supercell[50]	Became carbon negative By September 2019. Offset 200% of their direct carbon footprint. Offset 100% of CO2 emissions generated by players as they play Supercell games.	Yes (but rely on offsetting)
Timi Studio Group[51]	Explore how they will reduce their carbon emissions	No
Tigertron[52]	Uphold green practices wherever possible in the development of its games.	No
Ubisoft[53]	Carbon Neutral by 2030 (please see chapter 1.3).	Yes
Us two Games[54]	Reduce their carbon footprint by 30% by the end of 2022.	Yes
Wild Works[55]	Work with other companies to develop guidelines for the industry to follow in diminishing their collective carbon footprint.	No
TOTAL		**9/26 ; 34,61%**

Table 4. *Climate-related commitment of the game studios 'members of the P4P Alliance.*

34.61% of games studios have a quantified and time-based GHG reduction target, which is low given that members are part of the industry's flagship decarbonisation initiative.

This can be explained by the fact that many studios commit to deploying environmental themes in their games and to offsetting their emissions, not to reducing them directly.

This does not seem to be ill will, but a problem of method and the lack of consolidated activity data as pointed out by Freitag & al, 2020[15] (please see part 1.1.2).

49 Sumo Group, 2022.
50 Supercell, 2022.
51 Timi Studio Group, 2022.
52 Tigertron, 2022.
53 Ubisoft, 2022.
54 Ustwo Games, 2022.
55 Wild Works, 2022.

The emission items are not granular enough to initiate effective decarbonisation especially during the development process.

We can also assume that there is a vertigo in front of the decarbonisation magnitude to be achieved.

The studio with the most structured decarbonisation approach is Sumo Group[49]-UK (and Ubisoft, please see 1.3), it is a relevant inspiration for Flemish game studios.

Outside the physical decarbonization scope of this report, one studio, Dropledge[34]-India has an innovative approach mixing digital & physical to integrating environmental issues and on-ground activation into its games.

Aware of the current limitations of the data, methods, and tool available to decarbonize the games industry (and in the context of the energy crisis), initiatives are being developed to overcome them.

1.5 — Latest advancements to overcome limitations

The main advances are the conduct of additional research, consultation with players on game graphics options to save energy (and thus reduce emissions), the establishment of an energy efficiency indicator for games and the development of a carbon calculator tailored to the games industry.

— Baseline research

P4P is conducting (in 2022) baseline research[5] to enable more quantified and time-based commitments from its members.

There is a lot of room to improve the accuracy of game industry' GHG emissions accounting and others environmental impacts.

— Energy saving set-up

Microsoft is exploring new ways to make its Xbox console series X|S more energy-efficient, as the company sent out a recent questionnaire to members of the Xbox Insider program[56].

The company is exploring a list of potential graphical options across PC and console, by dialling back certain graphical features in games to save energy.

The survey asks if participants would be willing to play games with reduced graphics such as lower resolutions and frame rates.

56 Xbox Series X Energy-Saving Graphics Modes Reportedly Being Explored By Microsoft – Gamespot, 2022.

Depending on the survey results, game studios may not have to fill up the CPU & GPU as massive capacity of their games (for Xbox) console anymore.

One such example is the Xbox Series X|S standby option, which allows users to drastically cut down on how much power the console draws, around 20 times less in eco-saver mode when compared to instant-on mode.

In addition, it is now possible to download updates in energy saver mode[57].

— Game energy efficiency metric for Xbox console : power budget by game

During Green Games Summit 2021 – Green Coding[58] – Ukie; Rebecca Reed, Director of Electrical Engineering at Xbox, disclosed (in a video) extremely relevant matters for the decarbonization uptake by the studios within their game development.

"The conversation of how much of power we can use in different parts of game developments takes place with the X-Box hardware team and the game developers" – **Time code: 14:00**.

"We are really interested in incorporating (in our hardware) developers' feedback about the different scenarios that they are looking to develop in the next generation- or to know the different ways about utilizing the CPU & GPU" – **Time code: 14:44**.

"At scale right now, it is not possible to (for measuring energy consumption of rendering or changing frame rate) provide that information real-time" – **Time code: 16:40**.

"In the lab we can go and measure power output of that game, I would say game developers could also go into a lab scenario and make power measurement on their game and get a least a rough estimate of how each frame or how each part of the game is producing power on the console, but that is one of the big areas that I think is the future of carbon reduction in the gaming industry-trying to provide data in those type of decisions and questions" – **Time code: 17:20**.

"(What part can game developers play in achieving carbon neutrality)-Game developers get an opportunity to start chipping away at some of the power consumption- we have heard back from some studios and some game developers, that this seems to add to their list of things to do (above look at game performance and optimization) is to think about sustainability and power efficiency" – **Time code: 22:42**.

"We have a new design metric coming into our day-to-day work that we get to goal ourselves against, to reduce console power in a new unique way, over the next few years, we are going to see a lot of conversations around how games are developed, the size of games-where in a game do we need that max performance and where we can ramp it back-how do we create tools that are giving you a better insight into power efficiency -game developers are going to play a critical role in defining the metrics and the requirements for that suite of tools" – **Time code: 24:10**.

57 Xbox Series X|S Consoles Can Now Download Updates In Energy Saver Mode – Gamespot, 2022.
58 Summit Discussion: Green Coding – Rebecca Reed, Director of Electrical Engineering Team, Xbox, Ukie, 2021.

“Principles can happen immediately and then we can produce measurement that help enforce those principles (like carbon emission reduction)-we must learn through the process trying to achieve that goal instead of saying like oh it’s too hard I can’t ! – we at Xbox take pride in the high performance consoles that we want game developers to use them to their full potential, but we believe you can do that and we can be conscious of power efficiency as something that we can play with on a spectrum when you are developing a game-getting those tools in place (like a game power efficiency test bench in every studio) is definitely the next step“ – **Time code: 25:25**.

This interview is a mind-blowing contribution to the methodology process of game development decarbonization. Many thanks to Daniel Wood from Ukie for its relevant questions and Rebecca Reed from Xbox/Microsoft for its bright answers!

We draw heavily on it, to design the methodological recommendations contained in this report (please see chapter 3).

— Carbon calculator for game studio

In France the SNJV[59] (game studio trade-body) and Game Only[60] one of its regional members, intend to shape in 2023, an environmental impact self-diagnosis tool adapted to video game studios.

Outside the game industry, there are databases, methods, and monitoring tools, which we can use for the decarbonisation of game studios (please see chapter 3).

As we have seen in this chapter 1, the process of decarbonisation of the video game industry, including the studios (developers), has been initiated with a recommended decarbonisation trajectory (45% reduction in GHG emissions by 2030) and a structuring initiative, the P4P alliance.

However, there are some limitations that jam and slow down the decarbonisation process:
- **a confusion between carbon neutrality and Net Zero**, i.e., before committing to Net Zero, studios must first aim for carbon neutrality;
- **methodological grey areas** on the allocation of emissions in the pipeline;
- **a persistent lack of consolidated activity data**, especially for game development, digital infrastructure, and hardware manufacturing (there is no reference LCA database-ILCD type)[61].

Emerging initiatives try to overcome these issues, including those from the console manufacturers, the publishers, and the trade-bodies.

The current resources[5,6,7,8], nevertheless propose action principles/levers and their related solutions.

59 SNJV, 2022.
60 Game only, 2022.
61 European Platform on Life Cycle Assessment – European Commission, 2022.

2 — Overview of levers/solutions

What are the action principles/levers and their related solutions prescribed for game studios? As we seen previously, they are focus on the studio dimension, the project one (game development) is lightly address for the time being, due to the consolidated data lack and developers' involvement.

Prior to this solutions literacy review, we analyse the game industry trends that can have an impact on the game studios' decarbonization.

2.1 — Game industry trends

These trends relate to business models and emerging technologies. For a game studio, relevant decarbonization levers and their solutions may be under its business models and its uptake of emerging technologies influence.

Among these trends, Cloud gaming (streaming) is the most disruptive one as it will transform the whole value chain.

2.1.1 — COMMON AND EMERGING GAMING BUSINESS MODELS

The traditional business model for gaming[62] has been the console model. In short, companies mostly sell their gaming console at cost (or tight profit margin) while making money by selling games.

Digital games on PCs and mobile phones/tablets opened the way to added content formats (like streaming) and the way gamers interact between them and with the game itself and the monetization model adopted.

Globally, the freemium model is adopted by most studios. Freemium accounts for 82% of 130 billion in video game revenues in 2019[63].

The subscription model is used by >10% of studios worldwide. Subscription changes the traditional studio remuneration models, giving more power to the platforms. Subscription changes the traditional studio remuneration models, giving more power to the platforms.

In France, the SNJV[59] has released statistics[64] on the recent evolution of different business models adopted by French game studios. Please see following table.

62 Understanding the Gaming Industry and Its Business Models – FourWeekMBA, 2022.
63 Etude de besoin France 2030, Studios et formation – CNC, 2022.
64 Baromètre annuel du jeu vidéo en France – SNJV, Statista, 2022.

Business Model (6)	Description	Studio Share in %-2019	Studio Share in %-2021	Trend in %
Premium	Initial payment	59 %	48%	–11%
Freemium	Free with possibility of purchase	37%	47%	+10%
DLC	Initial payment plus integrated purchases	27%	32%	+5%
AD	Monetisation of virtual spaces via advertising	22%	22%	=
Episodic	Recurring payments to progress in the game	6%	8%	+2%
Subscription	Fixed recurring payments to access the game	2%	3%	+1%

Table 5. *Business models favoured by French development studios-source: CNC.*

Current trends are gradually being added to these business models:

- E-commerce within games with virtual platforms allowing the purchase of physical objects, a trend that could develop with the development of metaverse.
- Game portfolio subscription that allows varied consumption over a defined period, this is the monetisation model adopted by cloud gaming platforms (including subscription for one game).

We can assume that the evolution is similar for the Flemish studios.

To simplify, we can discern three types of models, please see following figure.

Figure 10. *Evolution of dominant game models.*

It is a fast-moving environment with a free to play at its peak and soon a cloud gaming all-in move for premium games with the end of physical consoles.

Each model is characterised by a different value chain which leads to a specific allocation of technical means and therefore GHG emissions, please see the following table.

Model (3)	Main GHG emissions sources
Premium	– Dedicated hardware (consoles) – Game development – Physical distribution (transportation, packaging, retail) – Digital platform distribution – Digital infrastructure (medium to large size)
Freemium	– Game development – Digital infrastructure (small to medium size) – Bandwidth consumption (low) – Advertisings (add to the game energy consumption)
Subscription	– Game development – Digital infrastructure (huge size) – Bandwidth consumption (extremely high)

Table 6. *Main GHG emissions by business models*

For their decarbonisation, game studios must focus on development because it is the perimeter they control and it will have repercussions on all the other emission items, e.g., the size of the game influenced the GHG emissions of digital distribution.

Emerging technologies impact the game development pipeline in terms of productivity, energy consumption, equipment... and therefore on its GHG emissions.

2.1.2 — EMERGING TECHNOLOGIES

These new technologies open new possibilities and change the GHG emission profile for game development, please see following table.

Technology challenges (6)	Description	Technological bricks	Example of impact for studios
Independent videogame engines	Real-time simulators performing geometric / physical calculations	– Game engine	Freedom from open-source video game engines (Unreal, Unity).
Computer Generation (CG)	Automatic generation of images and sounds from simple commands	– Artificial intelligence including machine learning.	Automation of digital creation steps, saving time.

Technology challenges (6)	Description	Technological bricks	Example of impact for studios
Virtual and augmented reality, including metaverse	Immersive digital content, variously integrating elements of the physical environment Metaverse: fictional virtual worlds with persistent and shared spaces, enabling 3D interactions.	– Immersion headsets – Sound Spatialisation – Cloud computing – 3D modelling	– Work on the spatialization of sounds and images – Creation of inter-actions between different virtual spaces (e.g.: interconnection of games)
NFT	Cryptographic token representing a unique object, which may be real or virtual.	– Blockchain	– Monetisation of unique content – Development of games such as «loot» games
DPU's	DPUs, or data processing units, are a new class of programmable processor and will join CPUs and GPUs as one of the three pillars of computing.	– Network data path processing – Cloud computing / Edge computing	– More computing resources available, i.e., the embedded CPU should be used for control path initialization and exception processing, nothing more. – Workload processing speed-up.
Cloud gaming	Storage of the video game on the cloud, allowing streaming access from any platform i.e., deportation of computing power to the data centres instead at the end-user.	– Cloud computing / Edge computing – 5G connectivity	Freedom from the performance characteristics of traditional platforms.

Table 7. *Emerging technologies-source CNC.*

These new technologies open new possibilities and change the GHG emission profile for game development.

Any data collection on a game development pipeline will have to consider these new technologies, e.g., the CG which, in terms of GHG emissions, on the one hand it reduces emissions (greater productivity) and on the other hand it increases them (AI training).

Cloud gaming is going to disrupt the whole value chain.

2.1.3 — CLOUD GAMING DISRUPTION: VALUE CHAIN AND ENVIRONMENTAL IMPACTS

The following figure (revamped from CNC[62]) try to capture the value chain transformation. Please see the following figure.

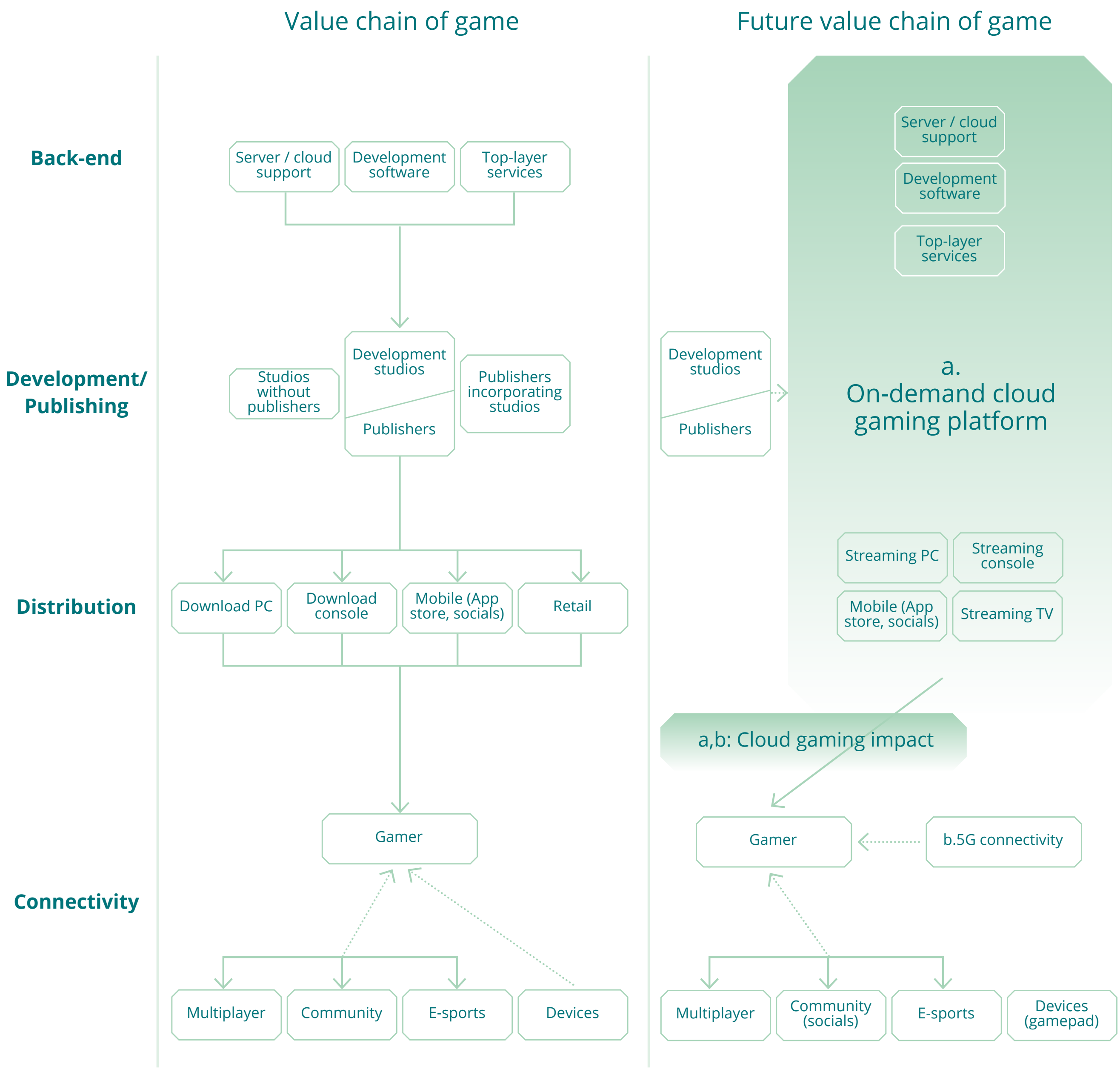

Figure 11. *On-demand cloud gaming platform impact on game' value chain. Source: revamped from CNC[62]*

With the emergence of integrated cloud gaming platforms, the vertically integrated players are expected to capture a larger market share after a temporary war between the many platforms entering the market.

The technical needs (network infrastructure) related to on-demand game, strengthen the role of network providers and telecommunication operators, thus they will become new entrants in the game industry.

It is still too early to discern with certainty the consequences for game studios, but if we refer to TV streaming platforms, we can anticipate a stronger demand for content, and therefore for games, to feed the platforms and differentiate them in the war for market share.

If there are more games developed, the GHG emissions of the studios will increase, hence the need to decarbonise their pipeline and even eco-design their games.

Playing in the cloud on a console with a TV, thus combining high data consumption from the cloud and the use of several high-impact devices (TV and console), is by far the most impactful practice (vs. playing on disk with a console and a TV, downloaded game with a computer, downloaded game with a console and a TV, etc.).

The environmental impacts of cloud gaming[20] depend on two factors: the user equipment and the high consumption of data, which increase the impacts of the networks and data centres used for the service: equipment, electricity, bandwidth, please see the following figure.

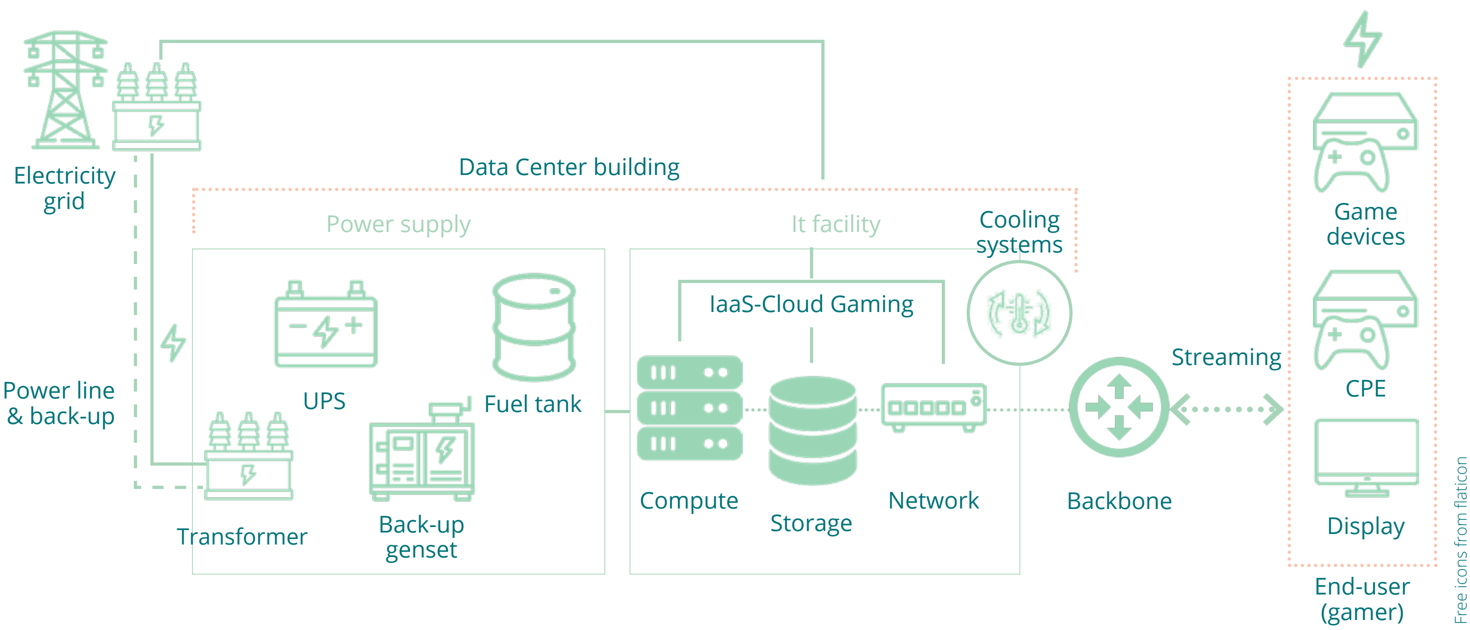

Figure 12. *Cloud gaming infrastructure.*

Depending on the uptake range, by 2030, GHG emissions could increase by 30% to 112%-Marsden & al, 2020. A more recent study[65] even estimates the induced increase in GHG emissions at between 44 and 211%.

The expansion of cloud gaming increases the need to optimise game development to reduce the computing requirements, the storage space and the network data needed.

Game studios will therefore have a decisive influence in mitigating the GHG emissions of cloud gaming.

In the following section we will detail the decarbonisation solutions and recommendations prescribed in the literature.

65 Streaming vs. CD... what are the environmental impacts of cultural services' digitalisation? – ADEME, 2022.

2.2 — Levers/solutions

The recommended levers and their solutions are articulated between solutions for studios and more specifically for projects (game development). To present them, we scan the existing literature, please see following table.

Resources (9)	Authors	Levers typology	Levers/ solutions for project
Annual impact report – 2021[5]	P4P	– Carbon footprint – Energy (renewables) – Circular economy – Game design environmental themes – Offsetting – Preservation	No
Green Games Guide[6] – 2021	Ukie/Games London	– Carbon footprint – Energy (renewables) – Efficiency in buildings – Energy efficiency hardware – Energy efficiency game – Transportation – Data storage efficiency – Game design efficiency – Game design environmental themes – Distribution – Coding efficiency – Game set-up efficiency – Distribution efficiency – Circular economy – Offsetting	Yes
Climate Handbook for Game Companies[8] – 2022	Play Create Green	– Efficiency in buildings – Transportation – Efficiency in services – Circular economy – Distribution – Marketing	Yes
Game Umwelt-Guide[66] – 2021	The German Game Industry Association	– Transportation – Efficiency in buildings – Waste sorting – Efficiency in purchases (office)	No

66 Tips for a climate neutral company – Game Umwelt-Guide-The German Game Industry Association,2021.

Resources (9)	Authors	Levers typology	Levers/ solutions for project
ITU-T L.1470[18] – 2020	International Tele-communication Union (ITU)	– Energy efficiency (network) – Energy (renewables) – Efficiency in buildings – Efficiency in services – Circular economy	No
Video game industry and digital sobriety[67] (unpublished) – 2021.	SO.Games	– Digital sobriety – Efficiency in buildings – Efficiency in services – Energy efficiency hardware – Game design efficiency – Code efficiency – Game set-up efficiency – Data storage efficiency – Efficiency in purchases – Circular economy	Yes
A Plug-Loads Game Changer: Energy Efficiency without Performance Compromise[68] – 2019	Mills & al, California Energy Commission	– Energy efficiency hardware – Code efficiency – Game set-up efficiency – Test bench – Gamer behaviour	Yes
Energy Efficiency across Programming Languages How Do Energy, Time, and Memory Relate?[69] – 2017	Pereira & al	– Programming languages energy efficiency	Yes

Table 8. *Decarbonization levers typology among dedicated literature.*
* Efficiency on the GHG emissions reduction and others environmental impacts.

The previous table help us to distinguish a pattern of levers for studios and projects.

The most comprehensive resources are those of the Green Games Guide and the So.Games Guide, unfortunately the latter has not been disseminated outside of some circles.

We also add solutions per levers, which are not derived from these resources.

67 Video game industry and digital sobriety (unpublished) – So.Games 2021.
68 A Plug-Loads Game Changer: Energy Efficiency without Performance Compromise – Mills & al, California Energy Commission, 2019.
69 Energy Efficiency across Programming Languages How Do Energy, Time, and Memory Relate? – Pereira & al, 2017.

2.2.1 — LEVERS/SOLUTIONS FOR STUDIOS (COMPANY)

The levers for the full range of studio operations are as follows, please see the figure below.

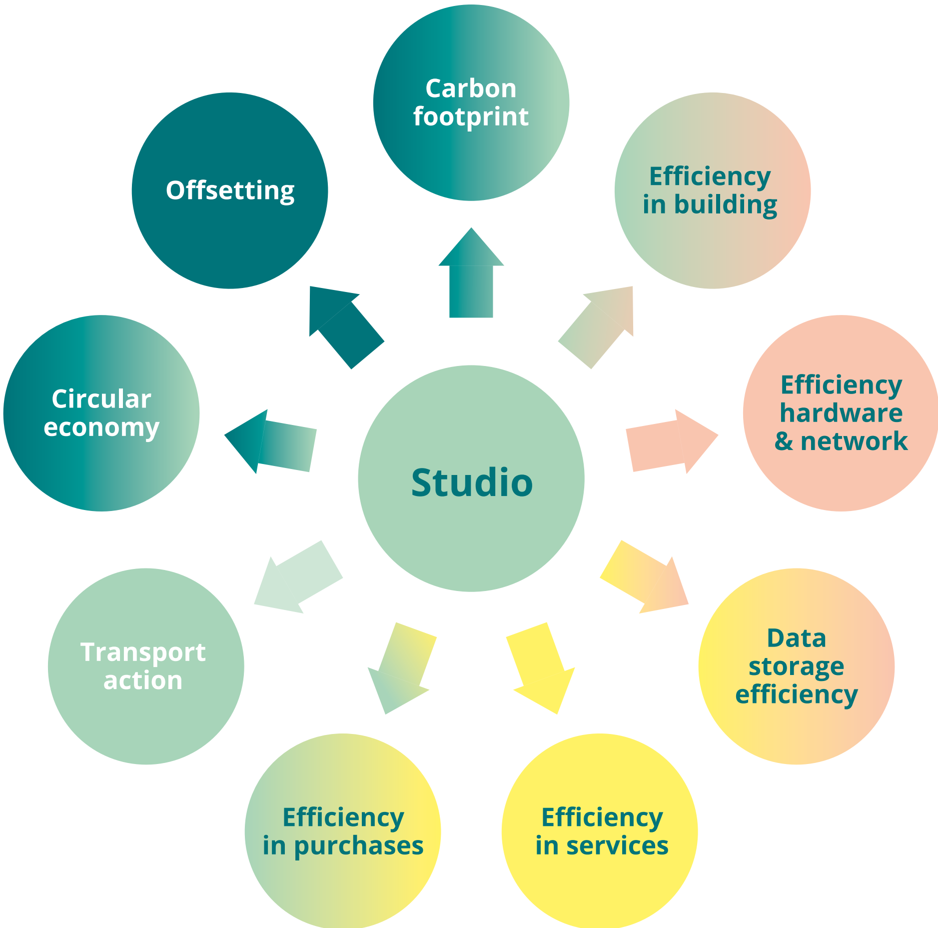

Figure 13. *Decarbonization levers for studio (company).*

In the following table we present the recommended levers and their solutions.

Levers (9)	Solutions (84)	Check box
1. Carbon footprint	1.1 Research about methodology, advice, and tools. 1.2 Set an internal working group and appoint internal ambassadors. 1.3 Set your scope (1,2,3). 1.4 Set your timeline. 1.5 Capturing internal activity data depending on your pre-defined scope. 1.6 Capturing external activity data from data centre and other suppliers depending on your pre-defined scope. . 1.7 Calculating your carbon footprint. 1.8 Set a decarbonization target that comply with the carbon neutrality trajectory. 1.9 Communicate and sensitize internally and externally on your carbon footprint (involve your community). 1.10 Conducting an annual carbon footprint allows you to measure the decarbonisation trajectory, improve the carbon action plan and minimise the rebound effect. 1.11 Share your learning with your peers: open source your process, work tools and conclusions. 1.12 Speak publicly at events about what you do to reduce carbon emissions.	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
2. Efficiency in buildings – office/premise energy use	2.1 Monitoring solution for efficient buildings (building management system). 2.2 Downsize office surface thanks to remote working. 2.3 Installation of energy conservation measures e.g., presence detectors and variable light controls to adjust the lighting required. 2.4 Set a target temperature of 19° Celsius for heating and 26° Celsius for cooling. 2.5 To reduce cooling needs of your server-room, confine your bays and to install only ASHRAE class A3 to A4 certified IT equipment, to increase the operating temperature of the equipment and thus use less energy-consuming techniques such as free cooling. 2.6 For cooling give priority to fresh air-conditioning systems use air outside when it is cooler than that inside a building, even during hot weather. 2.7 Choose adiabatic cooling, water is sprayed into the air before entering the existing free cooling system. As the water evaporates, the air is chilled. 2.8 Switching off equipment when not in use. 2.9 Make the most of natural light. 2.10 Light your office with light emitting diode (LED) bulbs or compact fluorescent lamps (CFLs). 2.11 Look into new zero energy usage technology that can improve your office's ventilation, cooling, and shading for windows. 2.12 Switch to a sustainable energy supplier. 2.13 Self-production of renewable energies. 2.14 Investigate energy supply innovation e.g., energy storage. 2.15 Controlled power saving and remote workstation restart (WOL) strategy by the user himself. 2.16 Be aware of the amount and volume of files you are sending.	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Levers (9)	Solutions (84)	Check box
3. Efficiency hardware & networks	3.1 Pool computing and storage infrastructures. 3.2 Optimise the operating conditions of internal servers. 3.3 Consolidate your server room (on-premises) regrouping physical servers in an optimized unique location. 3.4 Virtualize your servers, bringing several virtual software servers on a single physical server to gain flexibility. 3.5 Reduce mirror consumption (remote / on-site stations, paper / email / platforms). 3.6 Replace old equipment with more energy-efficient equipment e.g., for a GPU based on the following metrics: – Thermal Design Power (TDP), The lower the heat output, the lower the wattage consumption should logically be. – Total Graphics Power (TGP) – Total Board Power (TBP) – Max Power Consumption (MPC) Another alternative is to choose your equipment according to energy efficiency labels: Epeat[70], TCO[71] or Boavizta database[72]. 3.7 Equip employees working remote and in the office with energy efficient laptops. 3.8 Pool private and professional needs (same smartphone)- Bring your own device policy (BOYD). 3.9 Manage the scalability of the computer park in real time. 3.10 Review the purposes of the company's local network, not only to store and share not only to store and share work documents but also to manage documents but also to manage projects or replace one-to-one replace one-to-one emailing. 3.11 Use configurable sockets to program the automatic switch-off of internet boxes used in remote working. 3.12 Find the possible savings in your uses.	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
4. Data storage efficiency	4.1 Adopt a "Thin provisioning" approach, i.e., fill volumes A, B, C and leave the remainder switched off or at extremely low level. 4.2 Adapt the storage technology to the intended use i.e.., reassign data to increasingly less energy-intensive media as the data is used less and less (SSD, hard drive, band). The more powerful the disk, the more energy it consumes. The difference between less energy-intensive and more energy-intensive technology can vary by a factor of 30. 4.3 Minimise data collection ("Smart Data" versus "Big Data") and restrict replication to what is strictly necessary (direct access to the source data or the data lake). 4.4 Use the latest compression standard for your storage/ back-up and choose energy efficient storage.	☐ ☐ ☐ ☐

70 Epeat Registry – Global Electronics Council, 2022.
71 TCO certified, 2022.
72 Environmental Footprint Data – Boavizta Project – GitHub, 2022

Levers (9)	Solutions (84)	Check box
	4.5 Use a central storage system rather than having assets duplicated or assets saved per-team or individual.	☐
	4.6 Organise strike teams to delete unnecessary data and/or use a data management software.	☐
	4.7 Adapting data hosting to the location of the treatments and the consultation rate. Differentiating the location of data according to whether they are cold or hot (consulted regularly or not). Move the non-critical data into cold storage (less expensive and less polluting).	☐
	4.8 Optimise storage on the most suitable performance tier[73] (and thus avoid bidding on the best performing storage).	☐
	4.9 Do you need copies or even copies of copies of files, or do you need to send as many email attachments as possible?	☐
5. Efficiency in services	5.1 Choose a vicinity hosting services operator based on its green KPIs[74]:	☐
	– Power Usage Effectiveness (PUE), a PUE score of around 1.2, with the industry average of around 1.7;	☐
	– Water Usage Effectiveness (WUE);	☐
	– Energy Reuse Factor (ERF);	☐
	– Carbon Usage Effectiveness (CUE);	☐
	– Deployed Hardware Utilization Ratio (DHUR);	☐
	– Deployed Hardware Utilization Efficiency (DHUE);	☐
	– Compute Power Efficiency (CPE).	☐
	5.2 Give preference to operators who have ratified the European Code of Conduct for Energy Efficiency in Data Centres[75].	☐
	5.3 Use the green web foundation directory[76], which lists more than 500 hosting providers worldwide, all of whom are committed to using green energy in their data centres and rationalising their consumption.	☐
	5.4 Calculate your cloud workload' carbon footprint[77,78].	☐
	5.5 Make sure that your server is delivering needed and valuable computing or data storage (20% of VMs to be inactive or rarely used).	☐
	5.6 For short distance deliveries, try to favour transport by bicycle.	☐

73 Tier Classification System – Uptime institute, 2022.
74 Using Green KPIs for Large IT Infrastructures' Energy and Cost Optimization – Boban Celebic-University of Innsbruck, 2015.
75 Code of Conduct for Energy Efficiency in Data Centres – EU Science Hub, European Commission, 2022.
76 The Green Hosting Directory, as used by the apps – The Green Web Foundation, 2022.
77 Carbon footprint estimator for AWS instances – Benjamin Davy, TEADS, 2022.
78 Scaphandre – Hubblo-org GitHub, 2022.

Levers (9)	Solutions (84)	Check box
6. Efficiency in purchases	6.1 Limit the purchase of new equipment. 6.2 Define supplier codes of conduct or specific criteria in calls for tenders and give preference to suppliers who make concrete commitments on environmental issues. 6.3 A shared infrastructure for workstations (VDI technology: Virtual Desktop Infrastructure) can be a solution for limiting hardware purchases (a server can replace 24 workstations). 6.4 Avoid buying new equipment, by upgrading and reallocating equipment. 6.5 Give priority to repairable equipment. 6.6 Choose sustainable shipping options. 6.7 Buy local and/or organic food for your catering.	☐ ☐ ☐ ☐ ☐ ☐ ☐
7. Trans-portation	7.1 Shift to more climate-friendly means of transport, i.e., choose train over plane when possible. 7.2 Incentivise climate-friendly commutes, e.g., by supplying free public transportation passes. 7.3 Establish policies to reduce traveling between offices. 7.4 Create policies to minimize travels for sales and marketing conferences. 7.5 When flying, select airlines that offer a carbon offsetting option for a fee. 7.6 When flying, favour direct journeys. 7.7 When renting a car, prefer small, electric or hybrid cars. 7.8 Try to travel as light as possible.	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
8. Circular economy	8.1 Apply the waste hierarchy to your operations i.e., Reduce > Reuse > Repair > Recycle > Recover > Dispose. 8.2 Ban single-plastics use. 8.3 Replace individual desk bins with communal ones: 1 source-segregated recycling bins or stations for 6 people. 8.4 Encourage the reuse and recycling of supplies: cutlery, cardboard, packaging... 8.5 Use hand dryers rather than paper in toilets. 8.6 Use water bottles or purifiers instead of plastic bottles 8.7 Donate old equipment to charities, resource centre, local schools. 8.8 Carefully select the re-use facility. Not only to be able to claim, by means of the certificates given at the time of deposit, that they are fulfilling their obligations regarding their own computer waste, but also to be able to source reconditioned equipment. 8.9 Put back on the market equipment that can be reconditioned and for non-valuable equipment, recover components that can be reused or used as spare parts (internal repair workshop). 8.10 Put pressure on hardware producers to make use of long-lasting, eco-friendly, and easily recyclable or up cyclable materials. 8.11 Shift to sustainable packaging, from biomaterials and recyclable.	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Levers (9)	Solutions (84)	Check box
9. Offsetting	9.1 Carbon offsetting projects can cover communities, renewable energy, forests, biodiversity... Consider the offers to find the ones that best apply to your business and values.	☐
	9.2 For this you can also look at things you do not have control over in the production chain, such as suppliers and players.	☐
	9.3 Choose a certified offset project.[27,79,80]	☐

Table 9. *Recommended levers/solutions for the studios.*

The current body of decarbonisation levers is sufficient to ensure the transition at company level (although still perfectible) if the video game studios take it up.

These valuable recommendations focus on operations and are complemented by those for projects (games development).

79 Verified Carbon Standard (VCS) offsets – Carbon footprint, 2022.
80 Gold Standard, 2022.

2.2.2 — LEVERS/SOLUTIONS FOR PROJECTS (GAME DEVELOPMENT)

The levers for the game development are as follows, please see the figure below.

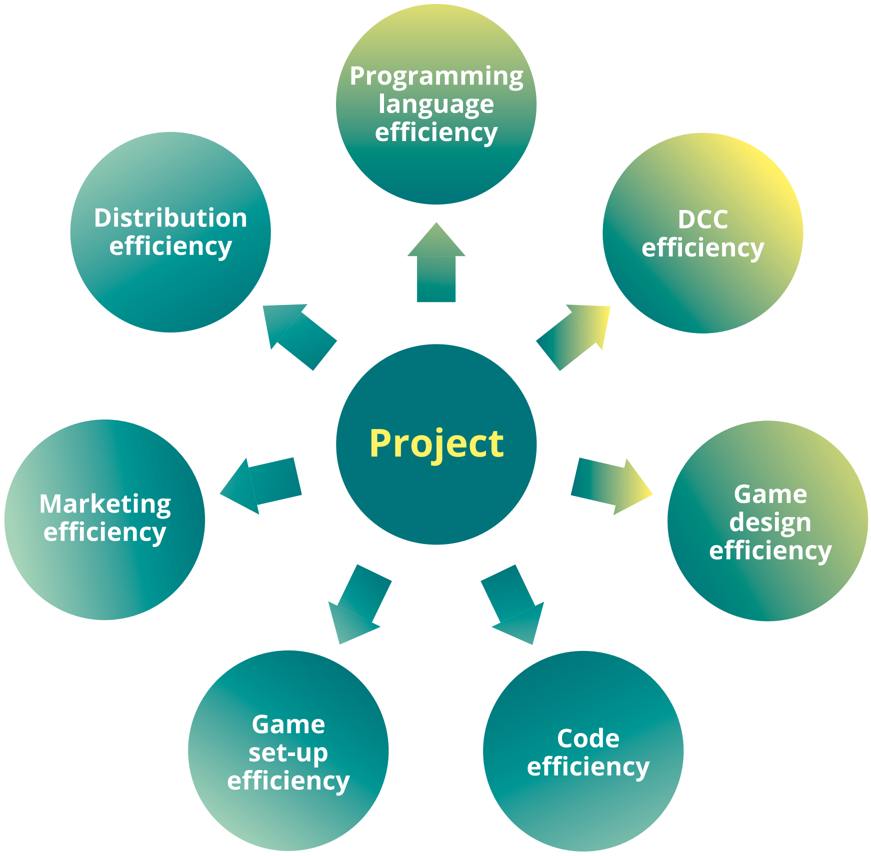

Figure 14. *Decarbonization levers for project (game development).*

It is a new field of research that holds many opportunities to reduce GHG emissions.

Indeed, the choice of programming languages, the digital content creation (DCC) efficiency, the game design, the coding, and the minimal set-up determine the amount of storage space needed plus the network data needed, and the power consumption to play it.

At the workshop organised by ISFE[81]/EGDF[82] on 22 and 23 February 2021, Supercell[50] explained that by adapting one of the of its games with a new rendering, the energy consumption had dropped by almost 25%.

A similar finding was made in the Californian study "A Plug-Loads Game Changer: Computer Gaming Energy Efficiency without Performance Compromise[67] i.e., the impact that code can have on energy savings.

81 ISFE – Europe's video games industry, 2022.
82 EGDF – European Game Developer Federation, 2022.

In the following table we present the recommended levers and their solutions.

Levers (5)	Solutions (49)	Check box
1. Programming languages energy efficiency* (energetic behaviour)	1.1 Choose the best software language considering energy, time, and memory usage[68]. 1.2 Compiled languages tend to be, the fastest and most energy efficient ones. 1.3 The C language is, overall, the fastest and most energy efficient. 1.4 The best languages according to a combination of energy, time and memory usage is as follows: – Energy & Time: C, Rust, C++ – Time & Memory: C, Pascal, Go – Energy & Memory: C, Pascal – Energy & Time & Memory: C, Pascal, Go 1.5 The Ruby language is, overall, the slowest and less energy efficient.	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
2. DCC efficiency	**Reduce the amount of data:** 2.1 Limiting the use of Physically Based Rendering (PBR). 2.2 Duplicate Publish / Load project trees. 2.3 Limit export/import actions. 2.4 Targeting changes (file part level > pixel level). 2.5 Do not bundle up all your 4K assets as your default install. 2.6 Reuse your assets from different versions of your games to avoid the having multiple versions stored in different places. **Optimise flows[83]:** 2.7 Limit the number of software programs. 2.8 Integrate an overlay harmonising the DCC environments. 2.9 Use an open-source simulation of DCC functions. 2.10 Implement a workflow management overlay. 2.11 Set a continuous software impact assessment. 2.12 You can optimise the loading of game engine tools to load only what is necessary for the user's needs, for example only artistic tools for an artist.	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
3. Game design efficiency	3.1 Try to limit the size of your game: length and resolution. 3.2 For the art direction of your game: is a photorealistic game relevant? It will impose heavier assets and a more performing machine to run than a cartoon game. 3.3 Implement green-nudge into the gameplay.	☐ ☐ ☐

83 Ecological Transition Infographic – Marine Oury, All Sides Pictures, 2022.

Levers (5)	Solutions (49)	Check box
4. Code efficiency	4.1 Set up a "clean coding group" to assess the impact changes to how you make your games can affect energy consumption and document the process.	☐
	4.2 Aim for a "clean" code allowing an easy maintenance and an easy detection/correction of bugs as well as optimising the number of machines on which the game developed can run (minimal set-up).	☐
	4.3 Establish strict coding rules that will be shared with the teams to write maintainable code that is readable by all. Thus, we will agree that an element of the product backlog or an increment will be described as "finished" when its impact on the resources required by the machine that will run it has been verified.	☐
	4.4 Conducting code reviews as the project progresses, to ensure that the rules established upstream have been respected.	☐
	4.5 Choose solutions that meet the needs and specifications of the project and that consider power consumption. Most of the time it will be a question of reducing the code and limiting the use of the resources of the GPU.	☐
	4.6 Improve the policy and management of unit tests. They ensure that the behaviour of the code and its energy efficiency is as expected that there is no regression with each new delivery.	☐
	4.7 Optimise iteration times and processes e.g., avoid data binarization.	☐
	4.8 Rely on smart asset and texture usage to limit GPU usage / memory footprint.	☐
	4.9 Reuse assets (retextured) from previous games.	☐
	4.10 Minimise the amount of processing power going into off-screen objects.	☐
	4.11 Avoid having objects updating on every frame i.e., reduce calls on every frame whenever possible.	☐
	4.12 Determining the trade-offs between live calculations and value lookups can help to reduce processing time.	☐
	4.13 Try to pre-compute as many things as possible rather than doing it at runtime for all users.	☐
	4.14 Minimise the amount of processing power going into off-screen objects.	☐
	4.15 Deliberately limit the number of FPS (e.g., to 60) to save energy.	☐
	4.16 Use "Download as You Progress" techniques: players no longer download the whole game from the start, but only what they need at the beginning, and the rest only as the player progresses.	☐
	4.17 Make packages as small as possible.	☐
	4.18 Run a python library which accumulates statistics about power consumption and CO2 emission during running code[84].	☐

84 Eco2AI – sb-ai-lab, GitHub, 2022

Levers (5)	Solutions (49)	Check box
5. Game set-up efficiency (minimal set-up)	5.1 Adapt your game's specifications to your audience's average set-up (for PC)-Use monthly Steam hardware & software survey[85]. 5.2 Avoid targeting special haptic controllers, VR headsets... 5.3 Propose an opt-in power saving mode. 5.4 Release on previous generation devices to fight obsolescence.	☐ ☐ ☐ ☐
6. Marketing efficiency	6.1 Give options not to play promotional videos automatically, and preferably not to do so by default (ban Autoplay). 6.2 For videos, if your game does not run in 4k, favour low resolution formats (< 1080), even if it means not offering larger formats. 6.3 Promote games that do not require an extremely high set-up. 6.4 Limit the use of in-game advertising (if it complies with your business models). 6.5 Prefer virtual rather than physical fairs/events, especially if these are likely to involve international air travel. 6.6 Calculates the carbon emission by the network traffic from your website URL[86]. 6.7 Informing players (end-users) about the carbon impact of their playing time on the game.	☐ ☐ ☐ ☐ ☐ ☐ ☐
7. Distribution efficiency	7.1 Favour digital distribution on platforms over retail physical distribution. 7.2 Consider whether your games are more suitable for download or cloud gaming and offer them for play in the best format. 7.3 Limit notifications for mobile games as much as possible.	☐ ☐ ☐

Table 10. *Recommended levers/solutions for the projects.*
*For programming languages[68], "a common misconception of energy consumption analysing in software is that it will behave in the same way execution time does. In other words, reducing the execution time of a program would bring a linear amount of energy reduction. In fact, the Energy equation, Energy (J) = Power (W) x Time(s), indicates that reducing time implies a reduction in the energy consumed.

However, the Power variable of the equation, which is not a constant, also has an impact on the energy. Therefore, conclusions regarding this issue diverge sometimes, where some works do support that energy and time are related, and the opposite was also observed"-Pereira & al 2017.

Levers/solutions to reduce the game development' carbon footprint and its consequences on end-using footprint , are emerging, although because their GHG emissions reduction benefits are currently difficult to assess precisely, they need to be further classified, documented, and evaluated.

85 Steam Hardware & Software Survey: October 2022 – Steam, 2022.
86 Website-carbon-calculator – Ricardo Dantas, GitHub, 2022.

Game industry trends, i.e., business models, technologies and the widespread of cloud gaming influence its decarbonization trajectory. **Through their game development optimisation, the game studios have a critical influence on reducing the GHG emissions of cloud gaming.**

In conjunction with these decarbonisation issues and stakes there are increasing levers / solutions to reduce carbon footprint on the studios and projects layers.

Nevertheless, **for the project side (game development) their efficient implementation is depending on the data consolidation (real-world data).**

To overcome this obstacle and the methodological limitations mentioned in part 1, we propose in the next chapter a bottom-up approach in co-construction with the Flemish game studios ecosystem.

3 — Decarbonization approach for game development

This approach can be delivered by setting-up a working group of 5 to 10 game studios that display the whole range of video game types i.e., AAA, independent, casual, VR …among all the platforms i.e., PCs, consoles, mobile games and developed on all kind of infrastructure i.e., on-premises, cloud-based, hybrid.

The representatives of each studio in this working group will ideally be those of the clean coding group (please see table 10 - 4/4.1). Ideally, the whole working group should encompass the 10 key roles in game development to finely modelized every aspect of game development:

- Delivery manager;
- Development manager;
- Game developer;
- Game designer;
- Level designer;
- Game artist;
- 3D artist;
- Animator;
- Sound designer;
- Q.A tester.

The target approach is to accelerate the decarbonization of game development through:

- the recommended ICT GHG emissions trajectory for 2030[18];
- peer engagement members to do everything they can to make accurate public statements i.e., no greenwashing / no data washing;
- the triple bottom line[87] evaluation framework: People, Planet, Profit (the three Ps) i.e., the decarbonization must comply with the game studio activity on these three dimensions, please see the figure, below.

87 The triple bottom-line – John Elkington, 2022.

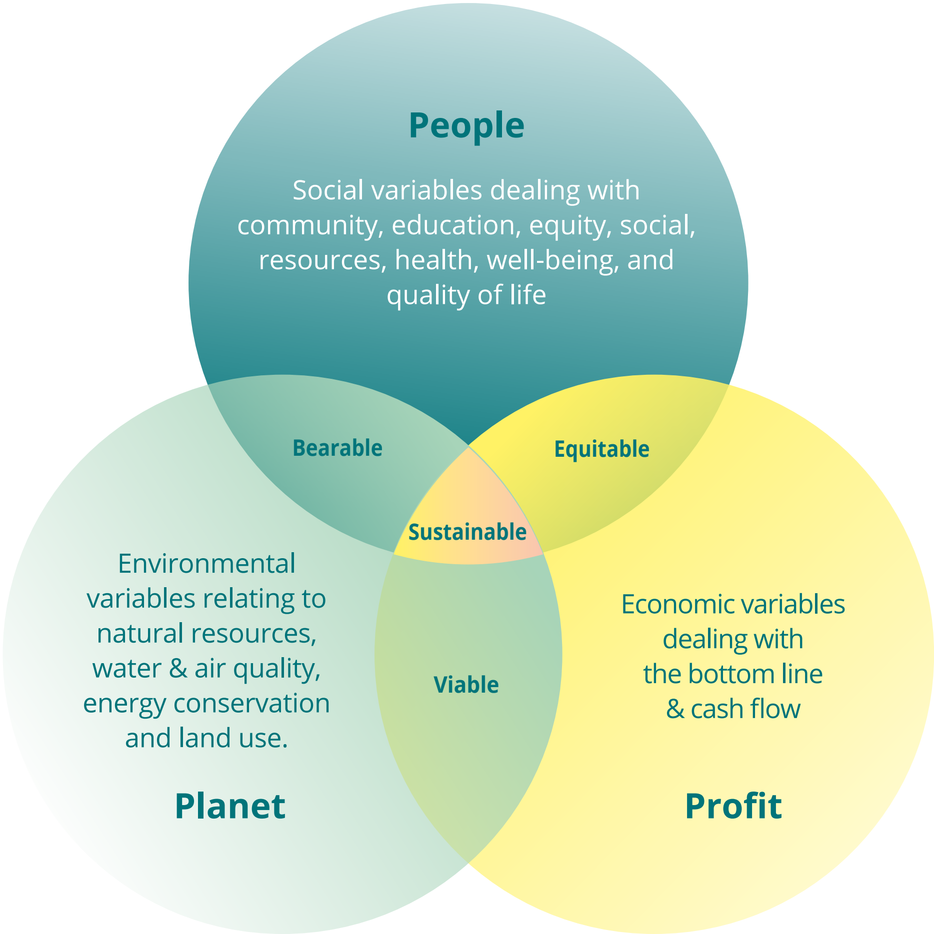

Figure 15. *The triple bottom line drive our decarbonization approach for game development.*

The expected results are:

1. Game development data consolidation i.e., provide real-world data through :
   — simplify and harmonize activity data collection;
   — improve emissions allocations to pipeline steps i.e., art, design, development, production marketing-during the work in progress i.e., pre-production, production, post-production, Q.A, release;
   — identify the allocation keys for the support function e.g., human resources, and the cloud services;
   — measure the GHG emissions of a game development from multiple kind of games ;
   — shape missing emissions factors per steps/task e.g., Design/GDD (game design document);
   — assess clean code leverage effect on GHG emissions reduction (if possible).

2. A sustainable design framework by game development steps and tasks or categories e.g., frontend, architecture, backend, hosting…

3. Support for the dissemination of the working group results at national level and implementation of collective and individual training courses on a voluntary base.

This work should be conducted in co-construction with the studios to validate or invalidate the methodology and the reduction actions in an operational situation, as a "top-down approach" exclusively initiate with non-professional developers (like this report) will not be efficient.

Obviously, the working group will be mentored by digital responsibility and environment specialists and will be coordinated by Pulse Netwerk[1] and VAF[2].

It is a team effort whose success will depend on the pursuit of the decarbonisation common goal for the entire ecosystem and on the complementarity of skills, please see the figure below.

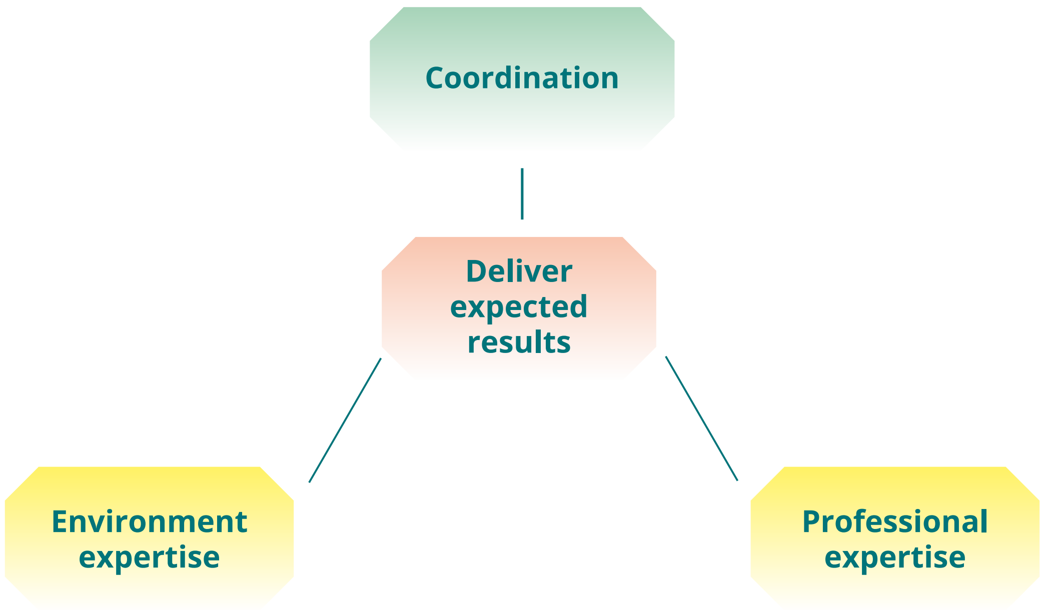

Figure 16. *Complementarity of skills needed to deliver the expected results of the planned working group.*

The first phase of the working group will be to break down their game development pipeline to establish a game development typology, which subordinate the measurement process (second phase) and then the sustainable design framework (third phase).

3.1 — Breakdown game development GHG emissions

This breakdown will help to identify the different kind of pipeline and functions among the game studio members. Correlated with their specifications: type of game, infrastructure, and prioritized platforms, it will shape a typology of game development. Please see below a generic & simplified game development pipeline.

Steps	Pre-production	Production	
Art	– Pre-Visualization – Level Diorama	– Paper Map – Prototype – Critical level /Objects – Non-critical level/objects – Texturing	– Set dressing – Set-ups – Critical path – Marketing materials
Design	– Game Design Document (GDD) – Level design – Level flow	– Paper Maps – Set-ups – Core loops – Play beats – Prototype	– Level fidelity – Mechanic' Setup – Story moments – Balancing
Development	– Technical specification document – Data pipeline – Character moves – Tool set-up – Infrastructure	– Assets – Prototype – Level fidelity	– Mechanic' Setup – Story moments – Balancing
Production	– Direction – Staffing plan – Budgeting – Final Schedule	– Legal – Pipeline management – Regulation compliance	
Marketing (If relevant)	– Market research – Distribution – Distribution partner – PR direction	– Industry reveal – Announcement – Developers interviews	– Game content – Community management

Table 11. *Simplified & generic game development pipeline.*

These are the fundamentals of game production, the working group may have to decide whether it is possible to aggregate tasks and allocate the corresponding GHG emissions to them.

Each step will be associated with:
— the technical list (bill of material) of the equipment used and their run time
— the cloud services and their run time;
— support function allocation;
— human resources allocation.

Steps	Post-Production	Q.A	Release
Art	– Optimisations – Lighting – Polish – Marketing materials – Release materials	– Release materials	– Release materials
Design	– Full experience – Polish	– Testing	– Testing
Development	– Full experience – Polish	– Certifications	– Certifications
Production	– Legal – Copywriting	– Internationalisation	– Internationalisation
Marketing (If relevant)	– Community management – Press' review – Media – Consumer's review	– Community management – Launch event	– Community management – Launch event

There are likely to be surprises in the structure of the pipeline depending on the type of games and the incorporation of emerging technologies (see Table 6), hence the importance of the presence of professionals.

The working group will also have to determine whether the marketing stage is relevant or irrelevant in terms of pure game development, i.e., whether it can include in the studio's footprint with allocation keys.

Once the pipeline typologies per game defined and mapped, we can move on the measurement phase.

3.2 — Measurement

The success of the approach is subordinate to:
— the fill of some key points;
— an efficient data collection;
— the deployment of a valid methodology;
— granular ad accurate calculation.

These tasks can be ease with the consultation of research papers and the use of open-source tools (and the support of Pulse and VAF experts).

3.2.1 — KEY FACTORS OF SUCCESS

The key points identified are:
1. Include scope 3 (upstream and downstream), even if it is harder to grasp than scope 1&2, as the results will be more relevant for the entire ecosystem;
2. Remove unnecessary collections and focusing on the key data collection i.e., being able to rightly allocate GHG emissions without loss of accuracy or dual allocation;
3. Solve the carbon data issue on hardware manufacturing and cloud services that are incomplete in the existing databases (hardware) or non-existent (cloud services). There is only one LCA of a server, the Dell R740[87] and the whole carbon footprint of cloud services is foggy despite interesting operators' studies[88,89], on their direct emissions (scope 1 & 2), it does not help to capture the bulk of their GHG emissions (scope 3);
4. Adapt a carbon footprint standardised methodology to the game development e.g., get rid of irrelevant emissions sources like freight and reach a better granularity in the IT equipment immobilised by the studios;
5. Keep it simple despite the wished granularity (typology will help in this matter);
6. Try to be as granular as possible to be able to a rational decarbonization (without altering the game development efficiency);
7. Facilitation of the working group to ensure consistency of involvement, contribution, and interest.
8. Establish cooperation ties with other initiatives and actors focused on sustainability : P4P, Ukie, Games London, SNJV...

The following step is the data collection and their calculation.

88 The Carbon Reduction Opportunity of Moving to Amazon Web Services – 451 research commissioned by AWS, 2019.
89 The carbon benefits of cloud computing – Microsoft Cloud in partnership with WSP, 2020.

3.2.2 — DATA COLLECTION

The game studios will drive the data collection with the support of Pulse & VAF experts and some open-source tools to ease the process, please see the table below.

Tools/DB (7)	Description	Features
Scaphandre[78]	Metrology agent dedicated to electrical power consumption metrics.	– measuring power consumption on bare metal hosts (scope 2) – measuring power consumption of qemu/kvm virtual machines from the host (scope 2) – exposing power consumption metrics of a virtual machine (scope 2)
ML CO2 Impact[90]	Machine Learning emissions calculator	– raw carbon emissions emitted by hardware type (GPU), runtime, provider, and region of compute (scope 2).
Experiment-impact-tracker[91]	Drop-in method to track energy usage, carbon emissions, and compute utilization of your system.	Record (scope 2): – power draw from CPU and GPU – hardware information – python package versions – estimated carbon emissions information
Green Algorithms[92,93,94]	Tool & methodology to quantify the carbon footprint of computation	Estimation of carbon Footprint based on (scope 2): – run time – type of cores – number of cores – model – memory available – platform used for computation – location – CPU usage factor – pragmatic scaling factor
Carbon footprint estimator for AWS instances[77]	Power consumption and carbon footprint of an EC2 instance	Estimation of Carbon Footprint based on (scope2): – instance type – AWS region – Run time

90 ML CO2 Impact, 2022.
91 experiment-impact-tracker – Breakend, GitHub, 2022.
92 Green Algorithms – Lannelongue, L., Grealey, J., Inouye, M., Green Algorithms: Quantifying the Carbon Footprint of Computation, 2021.
93 Green Algorithms: Quantifying the Carbon Footprint of Computation – Lannelongue & al, 2021.
94 GreenAlgorithms / green-algorithms-tool- Lannelongue & al, GitHub, 2021.

Tools/DB (7)	Description	Features
Environmental Footprint Data[95] (Hardware)	Hardware data repository. It aims to reference as much data as possible to help organizations to evaluate the environmental footprint of their information systems, applications, and digital services.	Estimation of hardware carbon Footprint (scope 2,3): – Desktop – Hard drive – Laptop – Monitor – Printer – San/NAS – Server – Tablet – Thin client – Workstation
Boagent[96]	Local API / sidecar / companion of a running application that computes and gives insights to the application regarding its environmental impacts.	Evaluate manufacturing and use phases impact:vwGHG (scope 2,3) – Abiotic resources depletion (minerals) – Primary energy usage : PE

Table 12. *Data collection-open-source tools/DB.*

Physical devices (sensors) can also be used to monitor your energy consumption on your IT equipment.

Once the data collection phase is complete, we will use the recommended methodology to calculate the footprint of the studios' game development.

3.2.3 — METHODOLOGY ADAPTATION

Recommendation ITU-T L.1420[18] 'Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies in organizations' gives guidance to ICT companies wanting to report their Scope 1 to 3 emissions.

It builds on the ISO 14064-2 standard and the GHG Protocol. The table below taken directly from ITU-T L.1420 summarises the different Scope 3 activities from the GHG Protocol which are material from an ICT company perspective.

95 Environmental Footprint Data – Boavizta, 2022.
96 Boagent – Boavizta, 2022.

Nomen-clature	Category	ICT application	Comment
S3A (note 1)	Purchased goods and services	Production-related procurement cradle-to-gate – Non-production related procurement: Paper usage cradle-to-gate Use of hotels – Related fuel and energy supply chain Optional: – Other non-production related procurement of goods and services (Note 2) – Manufacturing of vehicles, facilities and infrastructure – Manufacturing of office equipment – Product take-back services for sold products (as a purchased service not handled by the organization itself)	Based on LCA (Note 3)
S3B Capital	Capital Goods	Computer-ware cradle-to-gate (Notes 4, 5) – Related fuel and energy supply chain Optional: – Machinery (Note 6) production – Cradle-to-gate emissions from vehicles, facilities, and infrastructure	Based on LCA
S3C	Fuel- and energy related activities not included in scope 1 or 2	Fuel supply chain (Note 7) including transports. Infrastructure when data becomes available (Note 8) for fuel consumed by the reporting company – Energy supply chain including transports. Infrastructure when data becomes available (Note 9) for energy consumed by the reporting company.	The whole supply chain must be considered for electricity including infrastructure, land use; diffuse emissions of methane from oil and coal extraction; SF6 from transformer stations and handling of waste from electricity production Based on LCA. Electricity is of high importance for ICT industry. The fuel supply chain is also of great importance for other forms of energy (e.g., district heating) and for fuels consumed (incinerated) at sites.

Nomen-clature	Category	ICT application	Comment
S3D	Upstream transpor-tation and distribution	Transports of products purchased by the organization (Note 10) (from supplier to the organization; between organization's facilities; to customer if paid by the organization) – Transports purchased by the organization – Related fuel supply chain Optional: – Manufacturing of vehicles, facilities, and infrastructure – Storage during distribution – Consultants (Note 11) working outside facilities used by the organization	
S3E	Waste generated in operation	Optional: – Scope 1 and 2 emissions waste generated in operation that occur during disposal or treatment	Considered to be of low significance for ICT and does also have a high uncertainty
S3F	Business travel	Air, road, rail, and boat travel – Related Fuel supply chain Optional: – Manufacturing of vehicles, facilities, and infrastructure	Including the effects of remote working on employee commuting and other energy and/or indirect GHG emissions (Note 12).
S3G	Employee commuting	Air, road, rail, and boat travel including public transports and active mobility – Related fuel supply chain Optional: – Manufacturing of vehicles, facilities, and infrastructure	Including the effects of remote working on employee commuting and other energy and/or indirect GHG emissions (Note 13).
S3H	Upstream leased assets	– Computer-ware cradle-to-gate (Notes 14,15) – Related fuel and energy supply chain Optional: – Leased cars (Note 16) – Manufacturing of office equipment – Manufacturing of vehicles, facilities, and infrastructure	

Table 13. *ITU-T L.1420 GHG emissions accounting for ICT companies.*

Notes

Note 1 – Also, goods and networks, as defined in [ITU-T L.1410], are examples of indirect GHG emission sources

Note 2 – Services, e.g., finance, marketing, consultants, and data traffic, could potentially be of interest for further studies in the future, but for the time being little input data are available as a basis for inventories.

Note 3 – See 8.3.5.1.3

Note 4 – Use of PCs accounted for as "energy indirect GHG emissions"

Note 5 – Computerware includes PCs, servers, printers and copy machines etc. May in some organizations be part of leased assets

Note 6 – Machinery for production, development, test, and repair

Note 7 – Lack of LCA data for district heating notified

Note 8 – Lack of data so far

Note 9 – Lack of data so far

Note 10 – It is assumed that other Scope 3 (e.g., S3A, S3B) emissions contain their own transports

Note 11 – Consultants located in the organization facilities should be accounted for as employees for practical reasons

Note 12 – Energy use in visited organization neglected due to methodological problems/ uncertainty in data

Note 13 – Energy use in visited organization neglected due to methodological problems/ uncertainty in data

Note 14 – Use of PCs accounted for as scope 2 GHG emissions

Note 15 – May in some organizations be part of Capital goods

Note16 – Not recommended for inclusion because already included in commuting/business travels

This is the reference methodology, which must however be adapted to the specific case of game development including the rules of allocation.

The calculation of the footprint over 5 to 10 studios will allow the structuring of estimated emission factors for the missing ones.

With a quantified GHG breakdown of the different game development pipelines, we will be able to start structuring an operational eco-design framework.

3.3 — Game development sustainable design framework

For the time being, the available guidelines are insufficiently classified and evaluated, it is a catch-all (including in this report), it is time to move to the next step by building a real reference framework like those existing for the guide of sustainable IT good practices[97] and handbook of sustainable design of digital services[98].

The incorporation into the working group of the 10 main functions in development will contribute to the relevance of this sustainable framework and weave the articulations between the development domains/stages/tasks to deliver a holistic operational framework.

The sustainable design framework can be shape according three options:
- Pipeline steps;
- Key roles in game development;
- Categories.

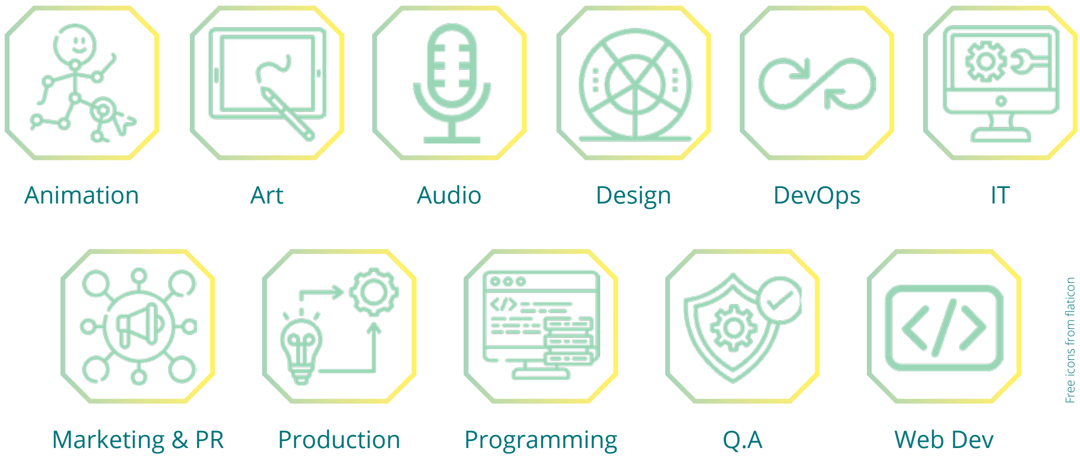

Figure 17. *Sustainable game development framework per categories.*

The criteria will be prioritized depending on their GHG emission reduction effect.

Prior the release, this sustainable framework will be submitted to the ecosystem for a review to integrate feedback and add more criteria.

Eventually, we can envisage a rating of these criteria to create a sustainable certification of game development.

The expected results of this working group will help to overcome the main blockages to studio commitment and action towards decarbonisation.

97 Guide de bonnes pratiques numérique responsable pour les organisations-minum_eco, 2022.
98 GR 491 handbook of sustainable design of digital services – Belgian Institute for Sustainable IT asbl/vzw – ISIT-BE 2022.

Conclusion

The games industry has already made great strides in knowledge, and this report is included in that iterative process of transmission and improvement.

Game development is the core of the game industry decarbonization as it conditioned the carbon intensity of the whole value chain especially with the rise of cloud gaming.

To meet the carbon neutrality targets, means must be deployed to solve the bottlenecks that block/impede the decarbonisation of industry.

Structured co-construction work with video game studios will help overcome a tipping point in the industry's journey towards carbon neutrality.

This bottom-up approach will advance knowledge, thus making an important contribution to the effective decarbonisation of industry, with a structuring effect on the entire Flemish and European game industry ecosystem.

This approach will also prepare the next step in the overall decarbonisation of the gaming industry, i.e., the conduct and running of a game development sustainable certification.

To do this, Pulse and VAF need the game studios collaboration who can make a strong contribution to the decarbonisation of the whole industry and be recognised and praised for this.

The project will be initiated during Pulse annual event on 15th of December in De Singel Antwerp.

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