Study on environmental sustainability at the Instituto de Astrofísica de Canarias and proposed actions

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EXECUTIVE SUMMARY

This study tackles five general aspects: travel, commuting to the IAC, computing, energy and consumption. Each of these is presented with a brief summary followed by specific recommendations. More detailed information is given in Annexes I to VI.

On page 8 will be found the final recommendation of the study and a table summarizing the data for the Central Headquarters of the IAC.

INTRODUCTION

The climate crisis, a phenomenon directly related to the excesses of our unsustainable lifestyle, has now impacted upon us with an unexpectedly high degree of virulence, to the point that we are now fast approaching the point of no return. To reverse this trend we have urgently to change our way of living.

The Covid 19 pandemic has disrupted our plans and working habits, many of which are highly damaging to the environment. The IAC must take this opportunity to return to a different kind of normality in which environmental protection, reduced energy consumption and sustainable working practices in all areas are seen not as an added burden but as the central pillar of all our activities.

The IAC has been working for many years in all areas of environmental management as far as its human and economic resources have permitted and always in compliance with the legislation in force. Nevertheless, like the greater part of Spain's public administration, it continues to follow the current model of consumption, which relies on the material and energy resources within its economic grasp. For some time now scientists have been warning that this situation will become unsustainable for the planet in the coming decades. We propose here a drastic review of our behaviour and present an environmental plan that will need the full support from all members of the IAC, along with the decisive action of the Directorate and Governing Council of the IAC.

This study concentrates on those aspects of the IAC in which a detectable improvement is possible. By way of introduction, we highlight the following questions:

- Our data are based on estimates by experts in each division of the IAC and may be considered to be fairly reliable.
- Our scaled estimates coincide with other astronomical centres in the USA[1], Canada[2] and, in particular, Australia[3], where the most detailed studies to date have been published on the environmental impact of astronomical activities.
- Most of our recommendations are neither arbitrary nor a matter of voluntary compliance: they follow the *mandatory* guidelines of the European Union[4].
- The IAC should set aside a specific part of its budget to manage and execute the present sustainability project at both of its headquarters and its Observatories.

- An essential element is to inform and increase the awareness of IAC employees. For this purpose we propose a programme of activities on environmental issues at both the IAC and the Science and Cosmos Museum.
- We recommend annual inspections to evaluate the level of compliance by addressing problems arising and updating activities in an effort to adapt to changing circumstances at the IAC and in state administrations.
- Given that the measures introduced are going to result in greater economy, a tally should be kept of all amounts saved and a fraction of these (50%, say) should be destined to the financing of further measures of sustainability and energy efficiency.
- The IAC Observatories (OT and ORM) have their own sustainability plans, some of them already under way and others being planned. The future integration of these different plans where they affect the IAC and user institutions shall be encouraged.

1. FLIGHTS

Summary. IAC personnel make approximately two thousand work-related journeys every year (45% international, 25% national and 30% to La Palma) which leave a total combined carbon footprint of about 620 tonnes of CO_2 equivalent (tCO_2), according to 2018 data. The greatest contribution (60%) comes from the Research Division, particularly from research staff, with an average of almost 3 tCO_2 per year per researcher. Twelve researchers in their work-related travels exceeded 5 tCO_2 (comparable to the global average emission per year per inhabitant).

Recommendations. The carbon footprint can be reduced by progressively eliminating unnecessary journeys to 1) conferences, 2) TAC-related short trips and group workshops, and 3) opting for remote observing. It is feasible to reach a 50% reduction in total emissions gradually over four years by encouraging a reduction in staff travels while maintaining external meetings and long stays by students and postdocs, always with a view to, where possible, restricting short-duration and lengthy journeys with an impact greater than 200 kg-CO_2/day (see Annexe 1).

We urge the Research Division, which is responsible for the greater part of the IAC's carbon footprint, to elaborate a plan to reduce and, in agreement with the Research Division Council, decide whether it is convenient to assign travel quotas to each research project independently of the availability of funds.

Annexe 1. Estimation of the carbon footprint of IAC travel

2. DAILY TRAVEL TO THE IAC

Summary. IAC employees travel more than 325,000 km per year in their private vehicles when travelling to work from their homes, which generates some 100 tCO_2 of emissions each year**.**

Recommendations. A study must be made of daily travel to and from work for the (almost 500) IAC employees. That study should be publicized, together with environmental information regarding its impact. Working from home, imposed by the pandemic, has clearly had a very positive impact in this regard. Now is the time to critically evaluate the possibility of implementing in the future those ways of working from home that have had the greatest success during this 'experiment'. Measures must be taken immediately, for example, to establish an order of priority for parking in the IAC: 1) electric cars and shared vehicles, 2) hybrid cars and 3) less powerful and less contaminating cars (types C and B of the DGT). Use of sustainable public transport must be encouraged if external funding can be obtained.

Annexe II. Estimation of the carbon footprint of daily travel to the IAC.

3. COMPUTING

Summary. The IAC has around 1,000 computers (600 desktops and 400 laptops) whose combined electrical consumption produces a carbon footprint of about 285 tCO_2 annually, in addition to two Central data-Processing Units (CPUs in La Laguna and La Palma) with a combined footprint of about 500 tCO_2 per year. Moreover, IAC researchers make intensive use of two supercomputers, La Palma and Teide-ITER, with a footprint of around 450 tCO_2 per year (due exclusively to the La Palma supercomputer, given that the ITER supercomputer uses 100% renewable energy). In total, IAC computers generate around 1235 tCO_2 annually; in other words, double the amount produced by travel.

Recommendations. The carbon footprint can be modestly reduced by running the CONDOR system exclusively on servers dedicated to intensive calculation, so that about 135 LINUX computers may be left in hibernation for a large part of the time. Similarly, measures must be implemented to turn off or hibernate computers in other divisions when they are not in use. Programs must also be optimized to reduce the cost in computer time and rationalize the use of computers (e.g. where possible by gathering together data dispersed among various computers and disks). However, since a reduction of the computing requirements of the IAC or a drastic improvement in CPU and supercomputer efficiency (both responsible for 80% of our computing CO_2 footprint) are as yet not contemplated, we should reduce our footprint by generating photovoltaically our energy needs on site, as outlined in the next subsection on energy.

Annexe III. Estimation of the carbon footprint of IAC computers: computers (Main Headquarters, CALP, DA-ULL) + supercomputers.

4. ENERGY

Summary. The total consumption of electricity in 2019 in the Main Headquarters (1400 MWh) and the CALP (1300 MWh) implies a respective carbon footprint of 840 and 780 tCO_2 per year. The total energy output from photovoltaic panels for that year was 44 and 25 MWh for the Main Headquarters and the CALP respectively. Although we generate less than 3% of our total consumption, some 40 tCO_2 per year are now being saved. The present installation of photovoltaic panels at the Main Headquarters (59 kW) can be gradually extended, and with reasonable investment and integration can reach 1000–1400 kW, thus generating 100% of our energy needs and reaching carbon neutrality. The same applies to the CALP.

Recommendations. The IAC could become a point of reference with regard to sustainability and must work so that administrations encourage and demand in its electricity supply tenders that the origin of all energy generated be 100% renewable.

Immediate reductions in electrical consumption can be made in small steps: activation of automatic illumination sensors only when environmental illumination is low; selective activation of the display screens in the corridors, etc. A significant reduction can be achieved gradually by 1) applying simple solutions such as allocating office space with regard to the thermal sensitivity of the occupant, 2) contracting environmental experts to carry out a study on passive air conditioning and possible improvements in insulation, and 3) attending to consequent air conditioning demands in succeeding years. An example might be to install double glazing in the most exposed offices. However, given that the buildings and activities of the IAC will not permit a drastic reduction in electricity consumption, a most important step would be to begin from the first year a decisive programme to install photovoltaic panels until reaching, if possible, a 100% balance between consumption and generation. Various options have been explored for the Main Headquarters (the installation of photovoltaic panels in correctly orientated parking spaces; maximum coverage of rooftops; fixing rows of panels above south-facing upper windows; photovoltaic panels in the tennis court, etc.) and it is calculated that there is space gradually to install adequate photovoltaic panels on sheds and buildings (up to 1400 kW with photovoltaic panels), which would imply carbon neutrality in the short term and near future (140% of present consumption). The electrification, at no cost to users, of the 150 parking spaces at the Main Headquarters would be included. Any excess energy generated would be sold to the grid (at 0.05 €/kWh at current rates), which would result in extra income for the IAC. At least 1000 kW could be installed, guaranteeing consumption and carbon balance right now. The present cost of panels (around 0.7 €/W already installed), saving in the electricity bill and foreseeable measures of support from the administrations make their installation both feasible and urgent. This is the most important recommendation of the present study that would result in a drastic reduction of our carbon footprint (up to 80%) and bring us closer to complete neutrality.

Annexe IV. Electric energy consumption at the IAC.

5. CONSUMPTION

Summary. Owing to its size and activity, the IAC generates an enormous volume of purchases and produces a great deal of waste products. On average around 35,000 euros-worth of products enter the IAC daily and several hundred kg of waste of all kinds are generated (ranging from refuse, paper, industrial residues, oils, metals, etc., to electronic and obsolete computer waste). We spend a total of around €13 million annually on purchases, of which about €1.5 million are allocated to computing equipment. This computing equipment constitutes one of the most critical sectors of IAC consumption, given its high cost and extremely short useful life. Indeed, its periodic updating implies a considerable carbon footprint: approximately 90 tCO_2 annually on computer purchases alone. Under the heading of expendable materials, there is a notable wasteful expenditure of resources involving around 50,000 printed sheets each month, along with single-use items in the cafeteria (paper table coverings, coffee capsules, plastic cups, etc.). On a more positive note, it is worth mentioning actions now being taken, including the installation of drinking water dispensers, which have greatly reduced the use of plastic bottles.

Recommendations. Our present unsustainable consumption is characterized by the use of products with an ever shorter useful life and the generation of increasing amounts of waste. The IAC must opt decisively for a ‘circular economy’ in which products are repaired, reused and exploited to the maximum. Such a change would not be easy to effect and would encounter resistance, since it goes against habitual practice. To bring about this change we recommend: 1) increased awareness through talks and workshops, 2) collective awareness campaigns (e.g. ‘Meat-Free Monday’, etc.), and 3) encouragement of precepts for good practices in the workplace (Annexe VI).

The acquisition of computer equipment must be supervised by a Technical Commission to ensure—apart from such basic necessities as hardware, operating systems and software—that criteria of durability, efficiency and quality prevail over those relating to the status of certain brands or the need for budgetary adjustments.

A quota system for printers must be implemented (as is done for emails) with the possibility to apply for personal extensions. The aim is reduce to one-third our current quantity of printing within the next few semesters, and later to an ‘almost zero printing’ phase. There must be a return to recycled paper and the use of black-and-white only printing mode, with only a few colour printers (which are six times more expensive to operate).

Concerning other aspects of less impact we must: 1) reduce the amount of IAC graphics and publicity material by concentrating on a single, easily updated publication, 2) after consultations with staff/users make further reductions in paper journals in the Library, 3) adjust the times of display of outreach and research screens to the maximum presence of staff.

Annexe V. Carbon footprint of IAC consumption.

EXECUTIVE SUMMARY OF THE SUSTAINABILITY PLAN

The IAC's carbon footprint can be reduced by up to 80% by imposing reasonable limitations on flying and by installing photovoltaic panels at the Main Headquarters and CALP. In the case of the Main Headquarters, a yearly investment of 175 k€/yr over 4 years (700 k€ in total) that would be necessary to achieve carbon neutrality would be far less than the subsequent yearly savings (430 €) in flight and electricity bills.

Data for Main Headquarters	**Present impact** (tCO_2/yr)	**Proposed** (tCO_2/yr)	**Total cost** (4 yr; k€)	**Saving** (k€/yr)
Flights[(1)]	620	300	0	250
Daily travel to IAC[(1)]	100	50	0	0
Computing[(2)]	(538)	(500)[(3)]	0	30
Energy[(2)]	840	0	700[(4)]	150[(5)]
TOTAL	**1560**	**350**	**700**	**430**

(1) Data for the whole IAC (Headquarters and Observatories).
(2) Data for IAC Central Headquarters only (they are similar for the CALP).
(3) The CO_2 footprint is already included under Energy.
(4) Final cost of installing 1000 kW photovoltaic panels at Central Headquarters.
(5) To the real cost of the electricity bill in 2019.

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COMPARISON WITH THE MAX PLANCK INSTITUTE FOR ASTRONOMY

The MPIA is an institute comparable to the IAC in terms of number of employees: 450 (IAC) and 300 (MPIA) in 2018. The MPIA has made public its data and is implementing sustainability measures similar to those of the IAC.

https://www.nature.com/articles/s41550-020-1202-4

DATA FOR 2018[1] (tCO_2-eq/yr)	**IAC+CALP**	**MPIA**
Flying	620	1280
Commuting	100	139
Electricity	1620	779
Heating	0	446
Paper	2	35
Computer hardware	88	29
Canteen, meat served	70	16
TOTAL	**2500**	**2724**

[1] Not included: Use of Hotel/Residencia and Observatories. Construction/renovation works.

Approximate average work-related travel emissions per employee (tCO_2-eq/yr): **1.4 (IAC), 3.9 (MPIA).**

Approximate average work-related total emissions per employee (tCO_2-eq/yr): **5.7 (IAC), 9.0 (MPIA).**

Comparison

Even though IAC personnel took 1846 flights against the MPIA's 1030, the IAC's carbon footprint is only half that of the MPIA because the majority of its flights are short-range trips to La Palma (600 flights) and to the mainland (450 flights).

The IAC+CALP uses practically twice as much electricity as the MPIA, although, if heating is included (the MPIA uses fuel oil) the carbon footprint is similar for both institutions.

The IAC purchased twice as many computers as the MPIA, but its carbon footprint calculation is more realistic (at the IAC laptops are considered separately from desktop computers, the latter having double the carbon footprint). This explains why the IAC's carbon footprint is three times higher.

The paper consumption footprint is very different: at the IAC we consider only printing paper, whereas at the MPIA both paper and cardboard are included. Our consumption is

$$500000 \text{ copies/yr} \times 2 \text{ g/copy} = 1 \text{ t/yr},$$

which implies a footprint of

$$1 \text{ t} \times 2.9 \text{ MWh/t} \times 0.5 \ (tCO_2/MWh) \approx 1.5 \ tCO_2/yr.$$

If we include other types of paper (leaflets, calendars, CCI reports, Annual Reports, etc.) our estimate will be increased by ≈2 tCO_2/yr. The MPIA declares 35 tCO_2/yr, which would imply 23 t of paper consumed, which seems very high.

Total beef consumption is similar for both institutes (≈1000 kg/yr), but the estimated carbon footprint (65 tCO_2/yr for the IAC against 16 tCO_2/yr for the MPIA) is very different. The IAC's figures are fairly accurate using available estimators:

1000 kg meat/yr x 0.2 kg protein/kg meat x 300 kg CO_2/kg protein ≈ 60 tCO_2/yr.

ANNEXES

ANNEXE I: ESTIMATED CARBON FOOTPRINT OF IAC FLIGHTS

CO_2 emissions from air transport: ICAO calculation, International Civil Aviation Organization (UN)[5].

SUMMARY: TOTAL EMISSIONS FROM FLYING AT THE IAC IN 2018

1846 flights (*) by 495 persons, CO_2 emissions from the flights: **623 tonnes of CO_2-equivalent (tCO_2).**

(*) Note: of the 1846 flights, 283 correspond to personnel external to the IAC (visitors), whose total amount of emission was 124 tCO_2. In other words, emissions caused by the IAC's own staff would amount to 500 tCO_2.

DATA

Typical data per passenger on a return flight from Tenerife to:

- Canberra (Australia) with two changes: 2.4 tCO_2
- ESO (Chile) with two changes: 1.4 tCO_2
- Boston (USA) with one change: 1.1 tCO_2
- Heidelberg (Germany) with one change: 0.6 tCO_2
- Madrid direct: 0.3 tCO_2
- La Palma: 0.03 tCO_2

Breakdown by destination. In 2018 IAC employees made the following journeys:

- Around 800 international flights, with emissions totalling 468 tCO_2
- Around 1050 national flights, with emissions totalling 155 tCO_2, of which 600 were inter-island, almost all of them to La Palma, with 20 tCO_2

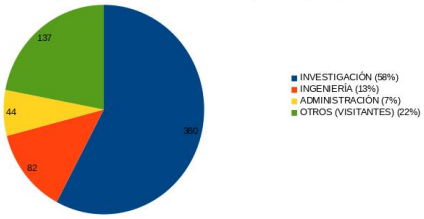


Fig. A-I.1. Emissions from flights in 2018 (tCO_2/yr) broken down by division

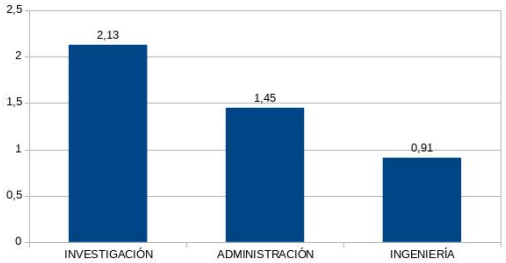


Fig. A-I.2. Mean emission (tCO_2 per person per year)

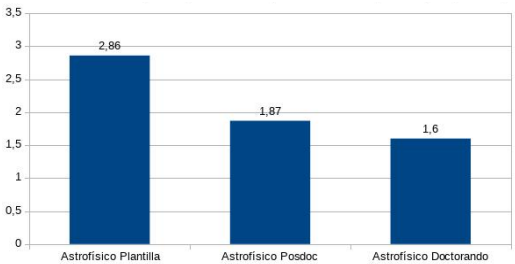


Fig. A-I.3. Mean emission (tCO_2 per person per year) for the Research Division

DISCUSSION

It is important to underline that the quantity of CO_2 emitted by flights could be underestimated by a factor of at least two with regard to the real effects of aviation on climate change:

> Airplanes, like cars, release carbon dioxide, but each flight also releases nitrogen oxides, water vapour and particulates that can contribute to global warming. When released at high altitude these other emissions usually amount to more than half of a plane trip's contribution to climate change.[6]

The emissions estimator used (the official one of the ICAO), does not take into account other contributions but only the CO_2 emitted. The discussion that follows suffers from that deficiency.

The total emission from IAC flights in 2018 was 623 tCO_2 (in 2019, the last pre-Covid19 year, CO_2 emissions were practically the same). IAC researchers generated almost 60% of those emissions (Fig. A-I.1). On average, an astrophysicist generates 50% more than an administrator and more than twice that of an engineer/technician (Fig. A-I.2). Postdocs and PhD students generate less emissions per person than staff astrophysicists, approximately 65% and 55% respectively (Fig. A-I.3). The staff/postdoc/student ratios are similar to those of the International Centre for Radio Astronomy Research (University of Western Australia).[3]

The histogram in Fig. A-I.4 (kg-CO_2/day of travel) can be used to characterize the impact of each proposed journey in order to discourage journeys that are 'very costly in CO_2'; i.e. those that imply long flights and short-duration stays.

IAC flight data provided by Eva Bejarano and Olivia Hernández. EXCEL programming by Isabel Plasencia.

ANNEXE II: CALCULATION OF CARBON FOOTPRINT FOR COMMUTING

Fig. A-II.1. Mode of commuting in Palma de Mallorca: present tendency vs. objective

In the absence of a detailed study of daily commuting for the IAC, we shall use data from the Greenpeace report for Palma de Mallorca,[7] which may be suitable for Tenerife (Fig. A-II.1), although the case for the IAC may be worse because there is far less walking involved.

IAC personnel commuting habits. Taking into account that there are around 500 people working at the IAC (including subcontracted guards, cleaners, gardeners, canteen workers, etc.), making two journeys per day to and from work, of which 50% travel 5 km or more, 40% approximately 3 km, and 10% less than 0.5 km (mean data from the Greenpeace report on commuting in Spain[8]), the total daily distance commuted amounts to 3,750 km. Assuming a conservative estimate of travel by private car of 40% (similar to that of Palma de Mallorca; see Fig. A-II.1), the total distance travelled per day would be around 1,500 km, which, for 220 working days per year, would amount to **325,000 km travelled by private car** and 66 tonnes of CO_2 equivalent annually (conversion factor used: 0.2 kg of CO_2 per km travelled; see left panel of Fig. A-II.2). Note that the total emissions estimated is a lower limit: that trips to the Observatories (60–90 km return journey) are not included; that the carbon footprint of public transport (bus and tram) are also not included; that the number of journeys by private car by IAC staff is probably greater than 40%; and that journeys greater than 5 km are counted as 5 km). For these reasons, we have estimated that around **100 tonnes of CO_2 equivalent per year** are emitted.

In summary, we need a **detailed study of commuting** by IAC employees and how to make it more sustainable, which implies knowing what average fraction of personnel use public transport, cars, motorbikes, bicycles, or walk, to get to the IAC.

Recommendations. There is probably little room for improvement with regard to persuading more persons to travel by bicycle or on foot (local orography does not help those who live at some distance) but something can be done to encourage car sharing and use of public transport. It would be advisable to encourage these means of transport (rather than penalize private transport) by using external funds assigned for that purpose. Possibilities: encourage use of buses and trams; grants to fund electrical bikes; offer part payment of petrol for shared cars; give privileged parking space at the IAC for shared, electric/hybrid and low-power/low-contamination cars (eco, C, B and others in that order).

Useful data on commuting in Spain[9]:

- Transport is now the greatest source of CO_2 emission in our country, far in excess of that generated by industry and electricity.
- In Spain some 43% of the population do not have a driving licence. Those that do dedicate up to 30% of their family budget to buy and maintain a car.
- Half of all car journeys cover a distance of less than 3 km, and 10% cover less than 500 m.

Useful data on commuting in the Canaries:

'In spite of the shorter distances travelled, the number of vehicles per inhabitant exceeds by 20%, and are considerably older, than the national average The low price of petrol and high dependence on privately owned vehicles for all journeys, however short, are deeply ingrained in the population of the archipelago, a circumstance that is further aggravated by a floating population of tourists encouraged to make their own journeys in hired vehicles while taking advantage of the fuel prices that are lower than in their countries of origin.' … 'Fossil fuels currently supply more than 80% of energy needs worldwide, but in the case of the Canary Islands this dependence is even greater, given that petroleum meets more than 98% of the energy demands of the islands. Petroleum completely dominates the transport, energy and heating sectors. This near-absolute dependence on petroleum is in sharp contrast with the abundance of renewable energy resources, the benign climate and available territory suitable for the rapid introduction of electric transport, among other favourable conditions in the archipelago.' (Greenpeace 2015 Report for the Canary Islands[10]).

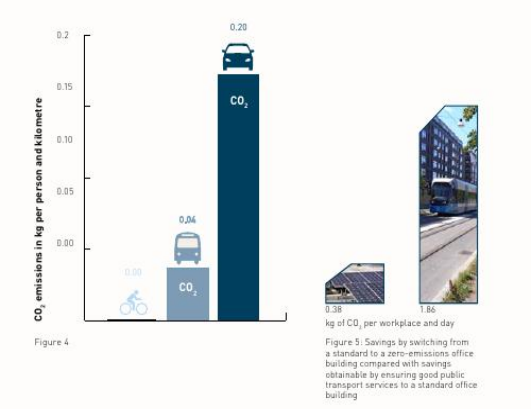


Fig. A II.2 (left). Public transport emits five times less CO2 than cars. Fig. A II.2 (right). CO2 saved by using public transport to conventional buildings is four times greater than using privately owned cars to future 'zero-emission' buildings.

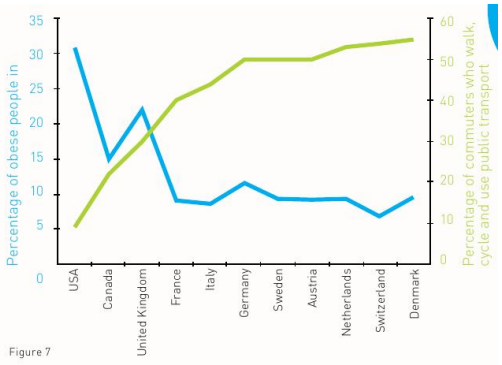


Fig. AII.3. Obesity (blue) versus main means of transport (green) for various countries. The Canaries are expected to lie well to the left.

(Source of information for Figures A II.2 and A II.3: 'A new urban mobility concept' Greenpeace, Germany[11])

ANNEXE III. ESTIMATION OF THE CARBON FOOTPRINT FOR COMPUTER ACTIVITIES AT THE IAC: COMPUTERS (MAIN HEADQUARTERS, CALP AND CC-DA-ULL) + SUPERCOMPUTERS

Source: IAC data[12,13]

ANNUAL POWER AND CONSUMPTION DATA FOR 2019

1) The 'La Palma' supercomputer has a power of 84 kW and operates full time (24/365), implying a total consumption of **736 MWh**.

(NOTE: It is a node of Spain's Supercomputing Network and its real use by the IAC is less than 50%, although the IAC has agreed to assume the total cost.)

2) Access to the supercomputer 'Teide-HPC' of the Technological Institute of Renewable Energies (ITER) with a total consumption of **788 MWh** (100% renewable energy). 25% of the time was taken up by the IAC in 2019 (315 MWh). We do not take the carbon footprint into account.

3) Central data-Processing Unit (CPU) at the Astrophysics Centre in La Palma (CALP): power = 49 kW, consumption at full time (24/365) totalling **429 MWh**.

4) CPU at Main Headquarters: power = 48 kW, consumption at full time (24/365) totalling **420 MWh**.

5) Computer Centre of Department of Astrophysics at the Faculty of Sciences of the University of La Laguna (CC-DA-ULL): 50 x 150 W computers working at 0.5 full time, consumption totalling **33 MWh**.

6) Personal computers. The total consumption of electricity through the use of personal computers amounts to **444 MWh** per year, as calculated on the following basis: The IAC has a total of around 1000 personal computers, of which some 600 are desktop PCs with an estimated average power per unit of 150 W (computer + screen). 135 of these PCs work full time (24/365), shared with the CONDOR system, and the rest (some 465 computers) are estimated to work a third of the time. There are additionally about 400 laptop computers with an average power of 80 W. They are also estimated to be working for a third of the time, since, workers having only a laptop use it during their working day, and those having both a laptop and desktop tend to leave the latter switched on in order to access local disks.

In some Areas of the IAC, such as the Research and Postgraduate Studies Divisions, users tend to be highly mobile and could substitute their desktops for laptops when the former end their useful lifetimes. This could effectively stop such workers from accumulating two computers (a desktop provided by the Division plus a laptop provided by their project), which would also reduce the electricity consumption by approximately 45% (even though at the cost of a higher monetary price: a laptop can cost between 1.5 and 4 times more than a desktop of the same capacity).

In all cases the purchase of laptops and of any computer system in general should be assessed by a technical commission that prioritizes criteria of

durability, performance and cost while always attending to the opinions of both experts and users.

Also to be investigated are possible savings from performing calculations in ‘local clouds’ (i.e. local in the sense of being independent of large multinationals). Such activities should be encouraged where possible.

Up to half (210 MWh) of the annual electricity consumption of personal laptops could be saved by running CONDOR exclusively on computers dedicated to intensive calculations (the so-called ‘donkeys’—*burros* in Spanish), thus implementing economy measures such as items 2 and 9 of Annexe VI and progressively making the transition to laptops as the need arises.

ANNUAL ELECTRICITY CONSUMPTION BY COMPUTERS (the sum of all the foregoing) **897 MWh (Main Headquarters + CC-DA-ULL + personal laptops) + 1165 MWh (CALP) = 2062 MWh.**

(For the calculation of CO_2 emissions we have used the conversion factor 0.6 kg of CO_2 per kWh of non-renewable energy, which in the Canaries amounts to 85% of the total -data for 2019 to 2021-.)

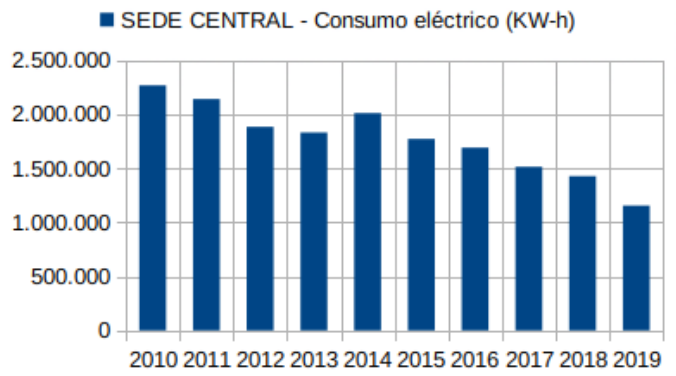
TOTAL ANNUAL CARBON FOOTPRINT FOR IAC COMPUTERS: 1237 tCO_2.

ANNEXE IV: CONSUMPTION OF ELECTRICAL ENERGY AT THE IAC

Energy is a key strategic aspect of the fight against climate change and of preserving the environment. The demand for energy at all levels continues to increase with each passing year, and new sources of energy become necessary in order to meet the growing demand. The clear future commitment in tackling emissions that contaminate the atmosphere is to close down power stations based on the consumption of fossil fuels and their derivatives, such as petroleum, natural gas and coal.

The case of the Canary Islands: 'Application of the objectives of directive 2010/31/EU, which establishes the compliance of Near Zero Consumption Buildings (NZEB) on all public and private sectors. The Canary Islands, because of their annual solar insolation and their mild climate, possess the most suitable framework for setting up the instruments to bring about the rehabilitation of all service buildings based on NZEB criteria, which should also be implemented in all new buildings. This plan must be applied to hotels, hospitals, public administration buildings, educational centres, sports facilities, commercial centres, etc.' … 'Plan to increase awareness in energy matters: The impression of abundant and cheap energy is deeply ingrained in the Islands on account of both the different fiscal system and the existence of subsidies with respect to the real cost of energy products. It is important to reverse this situation because the main actors in reaching the desired objectives are the inhabitants of the Islands'. Greenpeace 2015 Report for the Canary Islands[10].

The IAC has gradually reduced its electricity consumption and therefore its expenditure and carbon footprint while also increasing its own generation of photovoltaic electricity. That is a point worth emphasizing in the context of Spanish research centres, one that it is little known among the IAC employees. The figure below shows that **the Main IAC Headquarters has reduced its power consumption by 50% over the past decade.** We urge continuation along this path by generating our own energy and arriving within four years at a totally carbon-neutral consumption.



ANNEXE V: CARBON FOOTPRINT LEFT BY IAC CONSUMPTION

We have considered three aspects: the purchase of computer equipment, meat consumption in the canteen at Main Headquarters and paper printouts.

1) Purchase of computer equipment. In 2019 the IAC bought 114 laptops, 26 desktop computers and 5 other kinds of computers. Assuming that the total carbon footprint produced in manufacturing and transporting a laptop to the IAC amounts to 0.5 tCO_2 and that a desktop computer generates twice that amount (approximately 1 tCO_2[14]) we estimate that the total carbon footprint of the purchases of computers at the IAC comes to around **88 tCO_2** per year.

2) Meat consumption. Assuming the weekly meat consumption at the IAC canteen to amount to 50 servings of beef (x 3 days), 50 servings of pork (x 1 day) and 50 servings of chicken (x 1 day) and 125 g of meat per serving, the CO_2 footprint would be 65 (beef), 4 (pork) and 2.5 (chicken) tCO_2/yr; in other words, a total of around **71 tCO_2/yr** (FAO estimator [15]).

3) Paper printouts. The IAC prints out more than half a million copies per year, of which 65% are in colour, which are six times more expensive than black and white. Each sheet of paper weights 2 g and around 2.9 MWh are consumed in the production of 1 metric tonne of paper[16]. Given that some 0.5 kg of CO_2 are emitted per kWh, printing at the IAC leaves a CO_2 footprint of **2 tCO_2-eq/yr**.

Recommendations. 1) Pursue a 'think before you print' campaign. 2) Implement software to eliminate blank pages and unnecessary images before printing. 3) Print in black and white where possible on recycled paper. 4) Use tablets and laptops at meetings. 5) Accelerate, where possible, the setting in motion of the Digital Transformation Plan for State Administrations in an effort to eliminate all printing that is not strictly necessary.

Further recommendations

We include here several aspects of consumption not specifically dealt with elsewhere in the present study:

- As a major prerequisite, place great store in sustainability in all purchases and contracts undertaken by the IAC.
- Encourage 'green' software, such as the 'Ecosia' navigator[17], which plants trees with its earnings from advertising.
- Put the deposit for the recycling of batteries and electronic components in a more accessible location. Put up posters drawing attention to its existence.
- Avoid subscribing to journals and magazines that can be received by email.
- Avoid waste during cleaning (e.g. changing bin liners where not strictly necessary). Avoid aggressive chemical products. Improve selective waste disposal (e.g. compost in the canteen).
- Water consumption: reasonable irrigation of the garden (e.g. not irrigating on rainy days) and regular inspections of installations (toilet plumbing, etc.).
- Minimize the use of single-use materials in the canteen:

    - Paper cups: use reusable cups instead.
    - Plastic coffee capsules.
    - Tablecloths (some 22000 paper table mats are used annually. We propose two options: 1) an extra charge on the menu for paper table mats, the income derived to be sent to organizations that plant trees, and 2) selling and using tablecloths instead of their paper equivalent.
- Put up bilingual posters indicating where to recycle each item. On one day each week, use the canteen screens to demonstrate the correct use of the containers.
- When contracting canteen services remember to:
    - Encourage the use of reusable materials.
    - Encourage the purchase of local and seasonal products.
    - Reduce meat consumption. The IAC could join such initiatives as ‘Meat-Free Monday’, launched ten years ago by Paul McCartney[18] and recently adopted by French university canteens.

ANNEXE VI: THE TEN COMMANDMENTS OF GOOD PRACTICE

1) Minimize the number of paper printouts and avoid the use of colour.

2) Turn off lights, and hibernate screens and computers when not in use. Disconnect the plugs of equipment in hibernation and chargers, which continue to consume electricity.

3) Reduce the use of plastic. Change plastic recipients for stainless steel or glass ones, particularly when heating food in microwave ovens.

4) Play an active part in the recycling of electronic components (batteries, bulbs, etc.), plastic and paper.

5) Avoid the use of single-use materials. Make use of the water fountains to cut down on the use of plastic bottles.

6) Don’t waste water, which is in short supply in the Canary Islands. Inform maintenance staff of any leakages or losses through faulty plumbing.

7) If you can heat your work space, do it in a reasonable way by not wasting energy (e.g. do not use heaters with doors and windows left open).

8) Try to rationalize your commuting habits. Depending on the distance between your home and the IAC, give preference to walking, cycling, using public transport and car sharing.

9) Think twice before buying a new piece of electronic equipment. Base your purchases of computer equipment on technical considerations and absolute necessity. Prolong the life of devices by having repairs made where feasible. Avoid purchases just to use up remaining budget.

10) Ask yourself if the journey you are planning is really necessary. Limit trips to meetings on the basis of their necessity and taking into account their effect on the environment.

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