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SESAME

Synchrotron-light for Experimental Science and Applications in the Middle East

(SESAME)

Strategic Plan 2024-2028

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Preface / Executive Summary

SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East) is a third generation 2.5 GeV synchrotron light source located in Allan (Jordan), 35 km northwest of Amman. It is the first synchrotron light source in the Middle East and neighbouring countries, and also the region's first true international centre of excellence. It was established under the auspices of UNESCO, but is an independent intergovernmental organization. It is modelled on CERN (although it has very different scientific aims). Its membership currently stands at eight: Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestine, and Türkiye. Observers are: Brazil, Canada, China (People's Republic of), France, Germany, Greece, Italy, Japan, Kuwait, Portugal, Russian Federation, Spain, Sweden, Switzerland, United Arab Emirates, United Kingdom, and United States of America, as well as CERN (European Organization for Nuclear Research) and the EU (European Union).

SESAME aims at:

- Fostering excellent science and technology in the Middle East and the Mediterranean Region by enabling world-class research in subjects ranging from biology and medical sciences through materials science, physics and chemistry to archaeology.
- Building bridges between diverse societies and contributing to a culture of peace through international cooperation in science; and
- Helping to prevent and reverse the brain drain that is holding back science education and research in the region.

It was formally opened by His Majesty King Abdullah II on 16 May 2017.

The users of SESAME are based in universities and research institutes in the region. They visit the laboratory periodically to carry out experiments, generally in collaboration with peers from other Members, where they are exposed to the highest scientific standards.

This Five-Year Strategic Plan 2024-2028 provides information on the background and structure of SESAME and what has been achieved so far. It describes its vision for the next five years. It defines the capital funding that it needs to grow, and reports on the staff levels and operational budgets that will be needed till 2028.

1-Background and Introduction

1.1 SESAME's mission and vision

Mission

The International Centre for Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME) provides for collaboration in the Middle East and the Mediterranean Region with free access to all scientists of the SESAME Members in relevant areas of research, being also open to scientists from the whole world, in basic and applied research using synchrotron radiation or closely related topics. SESAME strives to foster scientific excellence in the region by providing scientists, including young scientists, with unique opportunities and facilities not available elsewhere in the region. It also aims at promoting a culture of science for decision-makers and the public at large.

Vision

SESAME will foster its function as an internationally recognized centre of excellence for synchrotron sciences, particularly in the areas of interest to the Members' research institutions and industry, and also as a world-class centre for innovation in science and technology.

1.2 Background and structure of SESAME

SESAME is a "third generation" light-source. The energy of the electrons is 2.5 GeV, and the circumference of the storage ring is 133 m. With the possibility of being exploited in up to twenty or more experiments operating simultaneously on independent beamlines, SESAME aims to offer scientists in the region and beyond a set of advanced analytical tools that enable world-class research in subjects ranging from medicine and biology, through materials science, physics and chemistry to health, agriculture, the environment and cultural heritage.

In the first phase, there will be eight beamlines. These beamlines, which have been selected on the basis of requests from scientists in the region, are the following: the (i) BM02 -IR (Infrared) spectromicroscopy beamline, (ii) BM08 - XAFS/XRF (X-ray Absorption Fine Structure/X-ray Fluorescence) spectroscopy beamline, (iii) ID09 – MS/XPD (Materials Science/X-ray Powder Diffraction) beamline, (iv) ID10 – BEATS (BEAmline for Tomography at SESAME) beamline, (v) ID11L – HESEB (HElmholtz-SEsame Beamline) soft X-ray beamline to be complemented by the ID11R –TXPES (Turkish soft X-ray PhotoElectron Spectroscopy) beamline, (vi) MX (Macromolecular/protein crystallography) beamline, (vii) SAXS/WAXS (Small Angle and Wide Angle X-ray Scattering) beamline, and (viii) VUV (Vacuum UltraViolet) spectroscopy beamline. The first three beamlines are already hosting users. Beamlines ID11L and ID10 have been commissioned and were officially inaugurated in June 2022 and June 2023, respectively. They will be receiving their first friendly users in the second semester of 2023 and will be open to proposals from general users as from the first semester of 2024.

SESAME is a widely available ‘user facility’. Scientists, including graduate students, from universities and research institutes typically visit the Centre for a few days, two or three times a year, to carry out experiments, frequently in collaboration with scientists from other centres/countries, and then return home to analyse the data they have obtained. In other words, SESAME is not a source of brain drain. Quite the contrary, not only do the scientists who visit SESAME bring back scientific expertise and knowledge, which they may share with their colleagues and students, but it also creates a motivating scientific environment that encourages the region’s best scientists and technologists to stay in the region or to return if they have moved elsewhere.

SESAME offers a means through which to promote solidarity and a culture of peace. Indeed, when scientists make use of SESAME's facilities and work together, they learn from each other's experience and develop technical respect for each other that is conductive to mutual tolerance, understanding and friendships that go beyond national and other boundaries.

1.3 Membership and governance

UNESCO is the depository of the statutes of SESAME. The membership of the SESAME Council is currently Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestine, and Türkiye. Observers are Brazil, Canada, China (People's Republic of), France, Germany, Greece, Italy, Japan, Kuwait, Portugal, Russian Federation, Spain, Sweden, Switzerland, the United Arab Emirates, the United Kingdom, and the United States of America, as well as CERN (European Organization for Nuclear Research) and the EU (European Union). Both SESAME and UNESCO are taking active steps to increase the number of Members.

The Council is the governing body of SESAME. Each Member and Observer may have up to two delegates on the Council. They may be accompanied to Council meetings by up to two advisers. A representative of the Director-General of UNESCO also sits on the Council. Each Member and the representative of the Director-General of UNESCO have one vote. Observers have no vote.

The current President of the Council, Professor Rolf Heuer, is a former Director General of CERN, as was the case of all the past Presidents of the Council.

Through the Council, the Members have full control over the development and exploitation of the Centre and its financial matters. Observers have no duties, but they have an important advisory role. They also have some privileges, for example, in the case of procurement and staff positions at SESAME.

The Council has a Finance Committee composed of one representative of each SESAME Member. This Committee is charged with the responsibility of advising the Council on all matters of financial management. The current Chair of the Committee is Professor Gina El-Feky (Egypt).

The Council is also advised by two Advisory Committees: the Scientific Advisory Committee for the operation of the current beamlines and the choice, design and follow up of future beamlines, and the Machine Advisory Committee for the initial operation of the machine and its technical infrastructure, and any upgrades that may be required during the first years of operation. The current Chair of the Scientific Advisory Committee is Dr Esen Ercan ALP (Türkiye/USA) from the Advanced Photon Source in the USA, and the current Chair of the Machine Advisory Committee is Dr Amor Nadji (Algeria/France) from the SOLEIL Synchrotron in France.

1.4 Current status of SESAME

1.4.1 Current status of the beamlines

SESAME currently has five operational beamlines and one is under construction. They may be broadly broken down into three energy ranges – infrared (< 1 eV), soft X-ray (100 eV to 2000 eV) and hard X-ray (>2500 eV). An overview of the six beamlines is given in Table 1.1.

1.4.1.1 BM02-IR (Infrared) spectromicroscopy beamline

The IR beamline (Fig 1.1) is the first completely new beamline to have been selected as a day-one beamline. It was implemented in the framework of a partnership agreement with the French synchrotron SOLEIL and came into operation in November 2018 to serve users of the infrared scientific community. The beamline design aims to provide an optimized photon flux in the mid-IR range while exhibiting significantly enhanced performance in brightness compared to a conventional source in both the far-IR and mid-IR regions.

Table 1.1: Summary of SESAME's operational beamlines and those under construction.

Beamline	Application	Year opened/ to open	Source	Energy	Spot size	Sample form
BM02-IR	Infrared spectromicroscopy	2018	BM (Bending Magnet)	0.001 – 3 eV	12-25 mm^2	any
BM08-XAFS/XRF	XAFS [XANES + EXAFS] and XRF (X-ray absorption fine structure [X-ray absorption near edge structure + Extended X-ray absorption fine structure] and X-ray fluorescence)	2018	BM (Bending Magnet)	4.7 – 30 keV	3x5 mm^2 to 20x5 mm^2	any
ID09-MS/XPD	Powder diffraction	2020	MPW (Multipole Wiggler)	7-25 keV	0.5 x 2.4 mm^2	powder - flat solid- thin film
ID10-BEATS	Computer tomography	2023	3PW (3-Pole Wiggler)	8-100 keV	72 x 15 mm^2	solid
ID11L-HESEB	XAS and XRF (X-ray absorption spectroscopy and X-ray fluorescence)	2023	APPLE II undulator	90-1800 eV	180 x 25 μm^2	flat solid
ID11R-TXPES	X-ray photoemission spectroscopy	-	APPLE II undulator	90-1800 eV	180 x 25 μm^2	flat solid

The IR beamline optimally exploits the infrared synchrotron radiation from both the ER (Edge Radiation) and the constant field of the bending magnet BM02, which can be considered to be the incoherent superposition of the two sources. Beam extraction is accomplished with a combination of mirrors collecting and focusing the infrared radiation through a CVD (Chemical Vapour Deposition) diamond window.

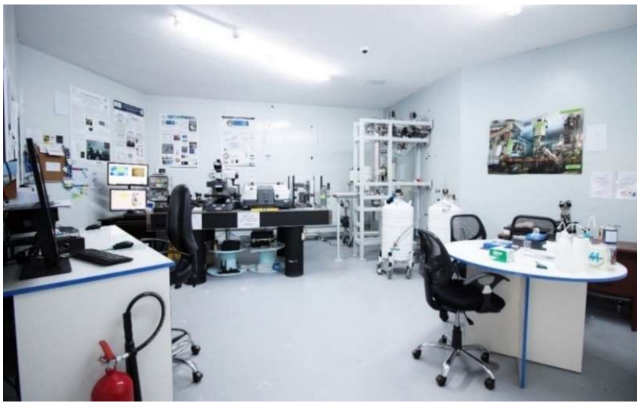


Fig 1.1: The IR beamline, the second SESAME beamline to have come online in 2018. This beamline is heavily used in archaeology and medicine.

Thanks to an agreement with INFN-CHNet, the network of the Italian INFN (Istituto Nazionale di Fisica Nucleare) which brings together laboratories working on the development and applications of analytical techniques for the study and the diagnostics of Cultural Heritage, the end station is equipped with a Bruker Vertex 70v FTIR (Fourier Transform Infrared) spectrometer coupled with a Hyperion 3000 IR-vis Microscope. An adaptive optical coupling box makes it possible to match the end station to the synchrotron radiation source. At a future stage, the beamline could be split into two branches of equivalent path lengths and performances.

The beamline also gives access to a second offline end station (the Globar IR source) equipped with an 8700 Thermo Scientific FTIR spectrometer coupled with a Thermo Scientific Nicolet Continuum XL IR-microscope, thus allowing micro-spectroscopic chemical imaging studies with DIC (Differential Interference Contrast) and fluorescence microscopy capabilities.

1.4.1.2 BM08-XAFS/XRF (X-ray Absorption Fine Structure/X-ray Fluorescence) spectroscopy beamline

SESAME's XAFS/XRF beamline (Fig 1.2) was the first

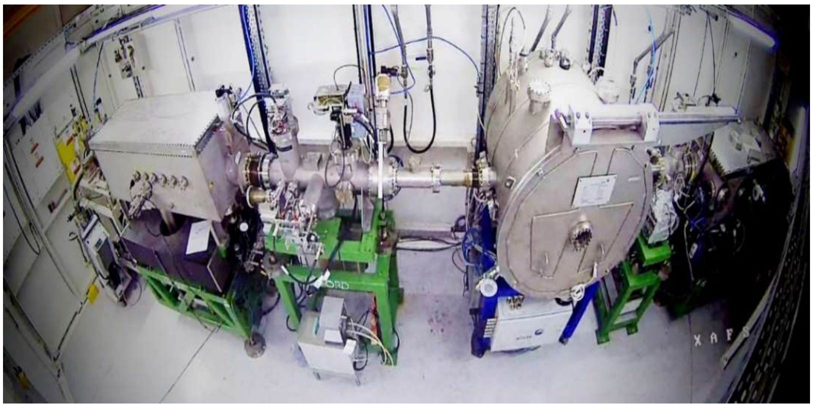


Fig 1.2: In 2018, the XAFS/XRF beamline became SESAME's first to come online. It is the most used beamline.

beamline to be installed and commissioned in the Middle East and neighbouring countries. It has been hosting users since July 2018.

Most of the beamline's components were previously part of a CRG (Collaborating Research Group) beamline owned by HZDR (Helmholtz-Zentrum Dresden-Rossendorf) in Germany that was installed and operated at the ESRF (European Synchrotron Radiation Facility), and donated to SESAME in 2012. The source is one of SESAME's bending magnets, and the optical configuration consists of a vertical collimating mirror, a fixed-exit DCM (Double Crystal Monochromator) and a focusing mirror. The DCM is a donation from the Diamond Light Source, and replaces the originally-installed monochromator donated by HZDR, whose mechanics were no longer fully operational. The DCM is equipped with slots for two pairs of crystals that can be exchanged by an in-vacuum translation. A Si(111) pair of crystals was delivered with the donated DCM, while a Si(311) pair was manufactured by the optics group of Argonne National Laboratory. With these two sets of crystals the monochromator allows measurements in the energy range 4.7 to 30 keV, covering most of the elements in the periodic table starting from Ti, but the absence of the collimating and focusing mirrors – the first has never worked and the second was missing at the time of installation of the beamline – greatly lowers the beamline's performance.

The experimental station is equipped with a movable optical table (six degrees of freedom). A heavy-duty sample stage, installed on top of the optical table, is used to centre the sample along the beam path. Small motion stages (rotation, swivel, x, y) can be added to align the sample with the beam.

XAFS data can be collected both in transmission and in fluorescence mode. Two ionization chambers are used before and after the sample to measure the absorbance of the sample, and a third ionization chamber is used for measuring the reference simultaneously with the sample. A simple gas-mixing system is available to fill the ionization chambers with the appropriate mixtures of inert gases. Fluorescence yield can be measured with a detector system based on 64 SDDs (Silicon Drift Detectors), developed by INFN and donated to SESAME. The energy resolution of a single square cell is 150 eV FWHM at 5.9 keV, and the detector array runs with its intrinsic built-in pulse-processing electronics. The parallel detection allows higher counts with low dead-time, which results in an increase in the overall efficiency of the instrument. A spare single-element SDD (AXAS-D), coupled with digital pulse processing electronics (XIA-Mercury), can also be used to collect XRF data.

XAFS spectra can be acquired in the step-by-step mode for each energy as soon as all the DCM movements have reached the desired positions. A continuous scanning mode is planned for future implementation.

1.4.1.3 ID09–MS/XPD (Materials Science/X-ray Powder Diffraction) beamline

The MS/XPD is SESAME's first ID- (Insertion Device-) based beamline (Fig 1.3). Open to users since December 2020, the beamline is dedicated to X-ray diffraction investigations from polycrystalline materials. Its wiggler source and main beamline components originate from the Swiss Light Source's Materials Science beamline that were donated to SESAME. The

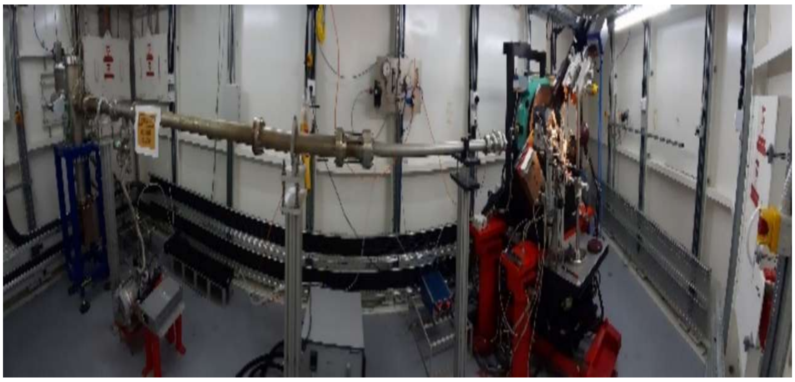


Fig 1.3: In 2020, the MS/XPD beamline became SESAME's third beamline to come online. Each call for proposals shows an increased number of users attracted to the beamline.

optical layout consists of a collimating cylindrical rhodium-coated mirror, a fixed-exit DCM equipped with a pair of Si(111) crystals for energy selection, and a second cylindrical rhodium-coated mirror placed face down to focus the beam vertically and bring the beam back to the horizontal trajectory. The second crystal of the monochromator is sagittally bendable to provide horizontal focusing on the sample. The available energy range is between 7 and 25 keV, with a flux at the sample of about 1013 photon/s at 10 keV.

The experimental station is equipped with a theta-2 theta diffractometer donated by the Diamond Light Source that allows measurements in transmission mode with samples in capillaries, as well as flat sample and thin film reflectivity studies. The detector is a PILATUS 300 K area detector donated by the Swiss company DECTRIS, fixed on the 2 theta arm at a distance of 740.4 mm from the centre of the diffractometer. The instrumental broadening is of the order of 0.015° at 18 keV, thus allowing microstructural investigations.

The read-out time of the PILATUS 300 K is of the order of 7 ms and its area is 83.8 × 106.5 mm^2, while one single frame of the detector covers about 6.4°. The average scan time in transmission mode is a few minutes, depending on the scattering quality of the samples. On the other hand, the flat samples can require measuring times of up to several hours. In this case, the area detector operates as a point detector by selecting the read-out of a single pixel.

Temperature-dependent *in-situ* measurements of up to 1000 °C are possible using a gas blower, and the MS/XPD beamline can be used for a wide range of applications, such as phase identification and quantitative phase analysis, microstructural investigations, PDF (Pair Distribution Functions), grazing angle and reflectivity measurements.

1.4.1.4 ID10–BEATS (BEAmline for Tomography at SESAME) beamline

A beamline for XCT (X-ray Computed Tomography) has been installed within the European Horizon 2020 BEATS project. It was inaugurated on 6 June 2023 (Fig 1.4).

It has been constructed and is being commissioned by a consortium of leading research facilities in the Middle East (SESAME and The Cyprus Institute), well-established European synchrotron radiation facilities and high-energy laboratories with decades-long experience in synchrotron radiation research and technology (DESY [Deutsches Elektronen-Synchrotron], Elettra, ESRF, INFN and PSI [Paul Scherrer Institute]), and more recently-founded synchrotron laboratories (CELLS-ALBA [Consorci per a la Construcció Equipament i Explotació del Laboratori de Llum de Sincrotró] and SOLARIS).

The beamline allows for various operation modes and ensures sufficient photon flux density in a filtered white beam (up to 100 keV) or monochromatic beam between 8 keV and 50 keV.

The photon source is a wavelength shifter with a peak magnetic field of 2.92 T. The front-end comprises photon

Fig 1.4: The BEATS beamline was inaugurated on 6 June 2023. It will receive its first users in 2023. Its full-field X-ray radiography and tomography capabilities extend the scientific possibilities of the Facility and the research opportunities in the region.

absorbers and stoppers, a mask defining the beamline aperture, a CVD diamond window, filters and primary slits. The main optical component is a DMM (Double Multilayer Monochromator) with two pairs of multilayer stripes coated on 500-mm-long Si substrates: [Ru/$B4C$]65 with 4 nm d-spacing for working energies between 8 and 22 keV, and [$W/B4C$]100 with 3 nm d-spacing for working energies between 20 and 50 keV.

The experimental station is located approximately 45 m from the photon source. It comprises secondary slits, a fast shutter to reduce exposure on delicate samples, a high precision sample positioning and rotation stage, and two full-field detectors based on scintillating screens and sCMOS (scientific Complementary Metal–Oxide–Semiconductor) sensor cameras, mounted on a common granite stage.

The beamline data acquisition, processing and storage infrastructure is designed to cope with a peak throughput of 1.1 Gigabyte of data per second, and up to 2 Terabytes of experimental data per day. The network and storage topology follows design principles established at the tomography beamlines of PSI and ESRF. The expected white beam flux delivered through a square millimetre at the sample position is between

1 × 1012 and 1 × 1013 Ph/s/mm², depending on the configuration of the photon absorbers, for a maximum usable beam size of 72 × 15 mm². With both multilayers, the expected energy resolution of the monochromatic beam is 3%, for a total monochromatic photon flux at 20 keV of 3 × 1011 Ph/s/mm² at the sample position.

1.4.1.5 ID11L–HESEB (HElmholtz-SESAME Beamline) beamline

HESEB is SESAME's first soft X-ray beamline (Fig 1.5). It was inaugurated in June 2022 and will be open to users in 2023.

This new beamline is being funded by the Helmholtz Association of German Research Centres. Five centres of the Association (DESY, FZJ [Forschungszentrum Jülich], HZB [Helmholtz-Zentrum Berlin], HZDR, and KIT [Karlsruher Institut für Technologie]) took charge of its design, construction, installation, and commissioning in close collaboration with SESAME. The beamline has been designed to cover the photon energy range of about 90 eV to 1800 eV. The source is a 1.7 m long Advanced Planar Polarized Light Emitter (APPLE) type II undulator. The period of the magnetic structure is 56 mm. The undulator can produce circularly polarized light with a selectable orientation of the polarization vector to allow studies of the magnetic properties of materials. The optical design follows the collimated PGM (Plane Grating Monochromator) concept as originally developed by R. Follath and F. Senf. Downstream of the PGM, a switching mirror enables the installation of a second branch that can work in the same photon range interchangeably as the ID11-right branch. The beam size at the focal spot is 180x20 μm² (h x v). The analysis chamber is based on a motorized manipulator with three sample positions and a temperature range between -160 °C and >800 °C coupled with a fluorescence detector. A sample exchange and transfer mechanism and the possibility of measuring the total electron yield are also available features.

Fig 1.5: HESEB is SESAME's first undulator beamline. It will be open to users in 2023.

Additionally, at the entrance of the chamber, there is the possibility of installing an elliptical focusing capillary, which serves a dual purpose: it will provide a focus of about 20 μm diameter for 2-D mapping of the samples and establish a differential pumping stage that, combined with a further stage, will allow the study of samples at atmospheric pressure (e.g. archaeological samples among others).

Soft X-ray analysis techniques are mainly used to understand the electronic structure and chemical environment of the atoms in the sample and can be applied to low atomic number elements that are critical for life, like Carbon Nitrogen and Oxygen. The techniques are surface-sensitive due to the high interaction probability of soft X-rays with matter.

1.4.1.6 ID11R–TXPES (Turkish soft X-ray PhotoElectron Spectroscopy) beamline

The optical architecture of HESEB implements a switching mirror that allows two experimental branches to utilise the monochromatic beam. Türkyie is constructing a TXPES (Turkish soft X-ray PhotoElectron Spectroscopy) end station for the second branch. This project is being coordinated by TENMAK (Turkish Energy, Nuclear and Mineral Research Agency). It is the first beamline to be constructed by one of the Members of SESAME.

1.4.1.7 Users' data management and information technology infrastructure

The collection of experimental data is the essential process of acquiring experimental raw data along with its associated metadata from the beamlines. The effectiveness of the experiments being conducted at SESAME heavily depends on the efficiency and reliability with which experimental data are collected. Each beamline at SESAME has its own DAQ (Data Acquisition) system that is intended, and is being primarily developed, to meet the requirements of the beamline users and scientists. The DAQ system also ensures that experimental raw data and metadata are not randomly generated but are stored together in standard, well-defined file formats as laid down in SESAME's Experimental Data Management Policy. In January 2021, a Data Collection and Analysis team was established to handle the rapid growth in the generation of data resulting from the use of the beamlines.

The already-existing Scientific Computing & Systems Communications team serves *inter alia* to provide the indispensable infrastructure needed to install and manage SESAME's experimental data pipeline and integrate in this pipeline the DAQ and all the control systems at the Facility.

The collection, processing, and management of the experimental data are major concerns at synchrotron facilities, particularly in the case of micro-tomography beamlines which is what SESAME's ID10-BEATS is. This beamline is the most data-intensive beamline at SESAME, and a single experiment can generate several terabytes of raw and processed data. The architecture of the computational and network infrastructure of BEATS encompasses all phases of the generation and handling of data, from the recording of raw data to the transmission of three-dimensional images to users. This infrastructure is the result of two years collaboration between SESAME and the IT (Information Technology) personnel of cutting-edge tomography beamlines at partner facilities, primarily PSI and ESRF.

1.4.2 Current status of the machine

SESAME's 2.5 GeV completely new storage ring was constructed in a project funded by the EU to the sum of €5 million and led and coordinated by CERN through the CESSAMag (CERN-EC Support for SESAME Magnets) collaborative project, by which CERN put its expertise at the service of SESAME, while ALBA played a role in magnet testing.

The storage ring magnetic structure is composed of 16 combined function bending magnets (dipoles with field gradient); 64 quadrupoles, of which 32 are long-focusing quadrupoles (QF) and 32 are short-defocusing quadrupoles (QD); and 64 sextupoles/correctors. Each cell consists of magnets (dipole, quadrupoles and sextupoles) and the vacuum chamber, supported by a separate girder. Each series of magnets is complemented by at least one spare magnet and spare parts for magnet repairs should this be necessary in the future. The first of the storage ring's 16 cells was installed in the shielding tunnel on 10 February 2016, and on 12 January 2017 a beam circulated in the storage ring for the first time. The first light was delivered to users on 17 July 2018.

Production of the various components of the magnetic system and related supplies was the work of five countries in Europe that produced the following: France (SEF: sextupole coils); Germany (FMB [Feinwerk-und Mestechnik GmbH]: vacuum chambers); Italy (EEI [Equipaggiamenti Elettronici Industriali]: dipoles power supply); Spain (Elytt: quadrupoles, and Nortemecánica: Girder); Switzerland (PSI: corrector power supplies and part of the controls); and UK (Tesla: combined function bending magnets).

The industry of four SESAME Members had also been involved, and CNE Technology in Cyprus and HMC3 in Pakistan had each assembled 50% of the sextupole coils produced by SEF in France and the ancillary parts related to the sextupoles/correctors (e.g. yokes, ties, etc.) that CERN had procured from various companies. SONMEZ in Türkiye had produced the magnet coils for the quadrupoles produced by Elytt in

Spain. TDK Lambda in Israel had produced the bulk of the power supplies. Moreover, Iran and Türkiye had provided manpower for the CERN team working on the project, namely an engineer from ILSF (Iranian Light Source Facility) who spent seven months at CERN and an engineer from TAEK (Turkish Atomic Energy Authority) who spent one year there.

The storage ring has been designed to store an electron beam current of 400 mA. In mid-2021, it was raised to 300 mA and the lifetime of the beam was increased to the order of some 24 hours.

The power needed for this current is delivered by four Elettra-type RF (Radio Frequency) cavities which are fed by four 80 kW, 500 MHz SSAs (Solid State Amplifiers) and controlled by Digital Low Level Electronics from Dimtel (Fig 1.6). The RF cavities, including the tuning cages and cooling racks, were provided by Elettra Sincrotrone Trieste S.C.p.A. thanks to the donation of €1.25 million by the Ministry of Education, Universities and Research of Italy through INFN. Elettra entrusted manufacture of the cavities to the Italian company CINEL Scientific Instruments. One of the SSAs (the prototype) was built by the SOLEIL Synchrotron, and the remaining three were constructed by the company Sigma-Phi Electronics in France, to which SOLEIL had licensed 500 MHz technology. DESY donated 90 waveguide components for the RF system.

The beam position in the storage ring is monitored by 48 of the 64 BPMs (Beam Position Monitors). These 48 BPMs are connected to Libera Brilliance plus processors, and 32 of them are equipped with GDX (Gigabit Data Exchange) modules that enable fast data archiving.

The storage ring is filled with electrons at 800 MeV at a repetition rate of 1 Hz, following which the energy in the ring is ramped up to its operational value of 2.5 GeV. The beam's relatively long lifetime makes one injection/day sufficient.

The storage ring is filled in only one filling pattern, that is in a multi bunch pattern in which 90% of the 222 bunches in the ring are filled with electrons while the remaining 10% are kept empty.

Injection into the storage ring is done by the upgraded BESSY I injector, which consists of a 20 MeV classical microtron and an 800 MeV booster synchrotron (Fig 1.7).

Fig 1.6: RF cavities (left) and RF solid state amplifiers (right).

Fig 1.7: Microtron and transfer line TL1 (left), and booster (right).

Given the age of the injector that made it urgent to replace it by a new 100 MeV Linac and the lack of the required resources for this, as a temporary, short-term solution SESAME embarked on a three-year programme to refurbish it yet further, particularly insofar as the microtron was concerned. Thus, it replaced the most critical parts by modern new ones. This was the case of the microtron control rack, the obsolete microtron auxiliary gun power supply, and the thyratron-based microtron modulator. The latter has been replaced by two solid state modulators constructed by ScandiNova in Sweden, namely the e-gun modulator and the magnetron modulator thanks to a donation of US$140K by INFN and a further US$140K by PSI. As a result of these changes, the microtron is now more reliable and performs better, and it is no longer a potential single point of failure for the machine. This has also dramatically reduced the MTTR (Mean Time To Repair) in the event of any failure of these systems.

Moreover, all the power supplies of the main magnet and TCs (Trim Coils) of the microtron have been replaced with modern new ones. The new TCs power supplies are bipolar whereas the previous ones were unipolar PS (Power Supplies) connected to a polarity-changing interface, and they are smaller in size and better able to recover communication with the PLC (Programmable Logic Controller) in the event of any electrical dip.

Similarly, all the power supplies of the TL1 (Microtron-Booster transfer line) have been replaced with modern new ones.

There have been numerous other donations for the machine or the infrastructure for the machine over and above those already referred to. Among them was the electronic equipment for the multi-bunch feedback system from CLS (Canadian Light Source) consisting of two Libera bunch by bunch front-ends, three Libera processors and five 150 W amplifiers. These amplifiers are of great use for SESAME's multi-bunch feedback system since only one was available, and it was to correct beam instabilities in the vertical plane, and there were none to correct those in the horizontal and longitudinal planes. The SOLEIL Synchrotron donated 28 SSA modules that were badly needed for SESAME's RF SSA system as SESAME had a shortage of spare parts for these modules. The Brazilian light source LNLS (Laboratório Nacional de Luz Síncrotron) donated a longitudinal kicker cavity, which will constitute the main part of SESAME's longitudinal feedback system. The

IAEA (International Atomic Energy Agency) procured spare parts for the machine valuing some US$26,000 and spare parts for the cooling system valuing some US$17,000. DESY donated a press brake machine, engraving machine, grinding machine and parts washing machine and the latter two have been installed in SESAME's workshop. CERN provided a GPS receiver, front-end computers and electronic boards, while Oxford University provided one vacuum XY-stage, UHV electrical feedthroughs, mechanical feedthroughs, and UHV high voltage ceramic isolator couplings.

1.4.3 Current status of the administrative infrastructure

The major innovations in SESAME's administrative infrastructure following the period of the first Strategic Plan (2010-2014) have been the construction of a solar power plant (SPP) and a guest house, both of which are crucial for the sustainability of the Organization.

1.4.3.1 Solar Power Plant (SPP)

The solar power plant (SPP) shown in Fig 1.8, which uses monocrystalline solar panels, was constructed by the Jordanian company Kawar Energy. The project was overseen by CCG (Consolidated Consultants Group) representing SESAME. The power plant was inaugurated on 26 February 2019 and for the first five years following this the operation and maintenance of the SPP is being carried out by Kawar Energy free of charge.

The SPP is located in Marj El-Faras, some 30 kms southeast of SESAME, on 80 donums (i.e. 19.77 acres) of land adjacent to JAEC (Jordan Atomic Energy Commission), which was allocated to SESAME for an indefinite period for the symbolic annual rent of JOD2/donum, that is, approximately US$250/year,

Fig 1.8: SESAME's solar power plant inaugurated in February 2019

inclusive of administrative fees. This land has been put at SESAME's disposal by the Ministry of Energy and Mineral Resources for use as a renewable energy plant. Each year, the DLS (Department of Lands & Survey) that was copied the Ministry's formal letter to SESAME assigning the land to the Organization for the aforementioned purpose, issues a contract with SESAME indicating the use to which the land is to be put and the symbolic annual rent to be paid.

Energy from the solar power plant is transmitted by cable to a nearby grid about 5km away, and from there to SESAME through the wheeling mechanism of the JEPCO (Jordanian Electric Power Company). Due to the distance of the power plant from SESAME, during the transmission there is a loss of about 5% of the energy, which is negligible. JEPCO transmits energy to SESAME at the time it is required by SESAME, and independent of when it was generated. Any excess energy not required by SESAME is retained by JEPCO to be used for its own needs. JEPCO credits SESAME for this excess power, and based on EMRC (Energy and Minerals Regulatory Commission) regulations, it does so to an amount not exceeding 10% of SESAME's consumption. The services provided by JEPCO and the conditions for payment are defined in an Agreement drawn up between the company and SESAME.

The average output of the solar power plant is equivalent to about 10 GWh/year. Given that the base SESAME power load at the time of construction of the solar power plant was on average estimated to be 35 MWh/month, i.e. a total of about 0.42 GWh/year, this means that the remaining energy should normally be sufficient for circa 4,500 hours of synchrotron operation. Thus, the current average output of circa 10 GWh/year will be sufficient for SESAME's needs for several years.

Thanks to the solar power plant, over the period March 2019 to May 2023, SESAME has made savings of the order of US$12,524,227 in terms of electricity consumption.

Funds (US$7.34 million) for construction of the SPP were granted by the EU through the Ministry of Energy and Mineral Resources of Jordan in the framework of a new renewable energy programme signed between the two parties in July 2016 in support of the deployment of clean energy sources.

SESAME is the world's first large accelerator complex to be fully powered by renewable energy thus making it the world's first carbon neutral accelerator laboratory. This makes SESAME economically, as well as environmentally sustainable. It has signed the UN's Climate Neutral Now pledge.

1.4.3.2 SESAME's Sergio Fubini Guest House

A guest house is an essential part of the infrastructure of any synchrotron light source. It serves two very important purposes. It provides a place close to the experimental Facility where users may attend to their experiments at any time of the day or night, and may easily go back to their rooms for sleep or relaxation. It provides an environment where users with diverse cultural and other backgrounds may get acquainted with each other, exchange ideas and plan joint research projects.

SESAME's Sergio Fubini Guest House, shown in Fig 1.9, was inaugurated on 4 December 2019. It is a three-storey building located on the premises of SESAME. It is 2,255.28 m^2 in size and has a footprint area of 720 m^2. There are 48 bedrooms in the guest house, each with a private bathroom, a study desk, TV and closet. Two are accessible to disabled people. There is a kitchenette and laundry room on each floor and a cafeteria and meeting room on the ground floor. The guest house is connected to the internet and SESAME's IP telephony system.

Fig 1.9: SESAME's Sergio Fubini Guest House on the premises of SESAME.

It is open to all users and visitors to SESAME.

The guest house was constructed by the Jordanian company Chart General Contracting Company, while quality assurance, supervision of the works, testing and commissioning assistance for the construction works were provided by INTEGRA AES, an Italian multidisciplinary consultancy firm in civil engineering, architectural design, urban planning and project management, in a joint venture with the Jordanian Consolidated Consultants for Engineering and Environment.

It has been named after the late Sergio Fubini in recognition of the €1.75 million that the Ministry of Education, Universities and Research of Italy through

INFN generously donated for its construction. Fubini was an Italian theorist at CERN who had held a number of significant positions as a faculty member at the MIT in Boston (USA) and the Universities of Padua and Turin in Italy, who had played an important role at the beginning of the SESAME project.

The total cost of construction of the guest house amounted to USD2,359,325 (excluding furniture, furnishings, etc.). Of this, US$2,052,575.00 were covered by the donation from Italy and the remaining US$306,750.04 were provided by SESAME from its 2019 operational budget.

The total cost of furniture, furnishings, the sound system in the meeting room, etc. amounted to USD140,996.42. From this sum, US$35,187 had been donated by SKF (Sharing Knowledge Foundation) and US$30,300 by the Swiss Federal Department of Foreign Affairs through the Embassy of Switzerland in Amman, with the remaining US$75,509.42 having been covered by SESAME's 2019 operational budget.

1.5 SESAME SWOT analysis

Strengths:

- Synchrotron light sources such as SESAME have become essential tools in a very vast number of subjects.
- SESAME is a users' facility that caters for users' needs.
- SESAME is more accessible to scientists from the region than to other light sources.
- SESAME is a third-generation light source which has the possibility of being exploited in up to twenty or more experiments operating simultaneously on independent beamlines; the source of twelve of these beamlines is an insertion device.
- SESAME is self-sufficient in electric power. SESAME's solar power plant will supply it with power at a very

low cost for many years to come. Consequently, SESAME is considered to be a green Facility.

- SESAME has a 48-room guest house on its premises.
- SESAME has the firm support of the IAEA, UNESCO, the European Union, and several of its Observers.
- SESAME is the epitome of a successful science diplomacy enterprise and a symbol of scientific excellence and achievement in the region.
- Thanks to the Seat Agreement between SESAME and Jordan that facilitates the delivery of entry visas to Jordan, users granted beam time at SESAME have easier access to the Facility than could be the case to synchrotron light sources located in some countries for which an entry visa may be more difficult to obtain.

Weaknesses:

- The budget provided by the SESAME Members is not sufficient. Underfunding has delayed the development of the Facility, has kept all sectors understaffed and the personnel overstretched, and jeopardizes the full functionality of the Facility.
- Political conflicts and instability in the region of the Middle East may slow down SESAME's progress.
- Most of the components of the SESAME machine and beamlines need to be imported from abroad which delays progress of work, in particular in the case of unplanned activities.
- Limitations on the movement of some sensitive components
- SESAME is lacking a reliable connection with the international Research and Education e-Infrastructure.

Opportunities:

- Countries in the region are allocating a limited budget for scientific research and SESAME will be a good option for scientists in the region to do their experiments through a shared common facility.

- SESAME is capable of attracting new Members from the region and beyond, which will help it develop at a faster pace.
- Adding new beamlines will open new avenues for scientific research and cooperation in the region.
- In addition to being a research facility, SESAME will be a centre for capacity building, specialized training, and education.

Threats:

- Political conflicts in the Region which would severely hamper SESAME's progress.
- Withdrawal from SESAME of a Member.
- Lack of a robust scientific research culture in some countries in the region.

2 - Improving SESAME's Present Capabilities

2.1 Consolidating the present scientific infrastructure

2.1.1 Sample preparation laboratories (ChemLab, BioLab, MatLab)

SESAME has three operational beamlines, with two more about to come on stream. With five open beamlines, the Facility enters a new, more user-oriented phase of its evolution. In this scenario, the need to implement sample preparation infrastructures to allow users to take full advantage of the beamlines is a priority. Moreover, the three presently-operational beamlines are all in need of essential upgrades. This section describes the upgrades needed to exploit SESAME's current facilities to their full potential. The timeline for these upgrades is an essential issue, and will critically depend on the decisions taken regarding funding.

To assist users in carrying out their studies and support the research conducted at the beamlines, SESAME needs to extend its capabilities and establish a series of support laboratories – initially three, namely a ChemLab, MatLab and BioLab. These support laboratories will also be needed for the training programmes for students and young researchers.

The ChemLab (Chemical Preparation Laboratory) should respond to the researchers' need for a suitable and safe place where they may perform chemical experiments and analytical procedures

The MatLab (Materials Sample Preparation Laboratory), a workshop with light mechanical and micromanipulation capabilities, will integrate SESAME's beamline capabilities. It will mainly serve as support for the preparation of samples by the users and beamline scientists, but it is also needed by the beamline scientists when they upgrade small beamline components and install new tools and equipment, and in the case of urgent user requests or needs during their beam time (e.g. repairing broken tools to save on their beam time, etc.).

The BioLab (Biological Preparation Laboratory) is needed for the biophysical studies using the techniques already available at SESAME. Once funding for the MX beamline has been secured it will be increased in size as support for the MX beamline users and provide a platform for high-throughput cloning, large-scale expression and purification of proteins, and a crystallization facility.

2.1.2 New optics for the BM02-IR beamline

In order to transport the IR radiation to the experimental setup, the optics of the beamline consists of a combination of mirrors that collect and focus the IR radiation. The first mirror was recently damaged in an event involving the electron orbit. It has been replaced, but the positioning systems of all mirrors need to be upgraded with more degrees of freedom, reliable remote controls, and beam visualization diagnostic.

2.1.3 Mirror optics for the BM08-XAFS/XRF beamline

At the XAFS/XFR beamline, EXAFS spectra are recorded by scanning X-ray photon energies over a range of the order of a thousand eV. The functionality of the beamline's three-element optical configuration (collimating mirror/double crystal monochromator/toroidal focusing mirror) is currently impeded by the fact that the bender of the collimating mirror is not working, and the toroidal mirror has never been procured. The monochromator is presently the only working element. As a result, the photon density at the sample is three orders of magnitude lower than the design values, and this makes it necessary to install collimating and focusing mirrors.

Installing these mirrors will also create an intermediate source for further focusing the beam using a secondary optical system that would significantly increase the attractiveness of the beamline by allowing microanalytical mapping methods including microXRF, microEXAFS and microXANES.

2.1.4 Remote sample changer for the ID09-MS/XPD beamline

As indicated earlier, the read-out time of the PILATUS 300 K modern photon detector of the MS/XPD beamline is of the order of 7 ms resulting in only a few minutes for the full scan of a sample. Yet the absence of a remote sample changer was greatly slowing down measurements at the beamline, and while an average of 2-3 minutes is required for a 2 theta scan, an average of 10-15 minutes was needed to change and align a new sample, and this was a misuse of beam time. Moreover, the door to the hutch, which has to be opened each time a sample is to be changed, weighs 110 kg and this was physically exhausting for the beamline scientist and not tenable. Therefore, to ensure the effective utilization and safe operation of the available photon flux, an automated sample changer, based on a robotic arm and a sample dispenser was needed. The robotic arm was procured in 2022 and the system is currently in the testing stage.

2.1.5 Sample environments

SESAME's different sources, beamline optics and detector systems already provide a wide range of instruments and experimental techniques. For many users, however, it is crucial to comprehend and characterize their samples in different non-ambient conditions. SESAME therefore needs to establish a pool of sample environment systems to meet their demands. This includes ovens, cryostats, hot blowers, or cryostreams to reach high and low temperatures, high-pressure and humidity cells, and magnets with different geometries. A few of these primary sample environment devices are already available, others will be installed in response to user demands, and some may be acquired or created as part of a Participatory Research Team agreement.

2.1.6 Supporting the archaeological and heritage sciences

The essential features of synchrotron radiation (SR) – a wide energy range, great brightness, and minimal divergence – allow information not typically available in a laboratory setting to be obtained. Thanks to these characteristics, synchrotron radiation has become an increasingly important study instrument in art, archaeometry, and the preservation of culturally-significant artefacts. Restoration and conservation, the analysis of alteration products, the identification of ancient communities' manufacturing techniques, and the study of human and animal evolution all benefit from using SR sources. Techniques such as infrared spectromicroscopy, computer tomography, soft X-ray spectroscopy, X-ray diffraction, X-ray fluorescence, and X-ray absorption spectroscopy (XAS), including EXAFS and XANES, are now widely used by researchers to study both inorganic materials such as metals, stone, glass, ceramics and pigments, and organic-based materials such as wood, paper, leather, fabrics and biological samples.

Given that SESAME is located in a region known for the exceptional richness of its archaeological, cultural and natural heritage, where many highly-esteemed museums, collections, research institutions and universities have departments dedicated to scientific and art historical research, it should impose itself as a highly-useful and versatile research tool offering the highest analytical finesse for researchers, conservators, and cultural heritage specialists.

To obtain the best results, the research scientist must be able to discuss his/her research aims meaningfully with beamline scientists. This will require special attention and efforts in order to build bridges with the relevant archaeological and heritage communities. The results of this effort can be extremely rewarding, as art and history have multiple levels of impact. Moreover, heritage studies can give a newsworthy entrance point from which attention can be brought to a more extensive exploration of SESAME and the opportunities it offers.

2.2 Improving the present capabilities of the SESAME machine

2.2.1 Improving machine reliability, performance, beam availability and beam stability

The machine is operating smoothly. It is showing a good beam availability and providing a beam that has a relatively long lifetime. However, the capabilities of the machine need to be enhanced and for this there is a need for upgrades. There is also a need for maintenance works. The most urgent of these actions are the following:

- Continuation and finalization of refurbishment of the injector system.
- Acquisition of the spare parts required for the machine.
- Enhancement of the technical laboratories through the acquisition of the equipment needed for testing, measurement, and maintenance.
- Improvement and upgrading of the cooling system.
- Installation of a pinhole camera (X-ray diagnostics beamline) for precise beam size and instability measurements.
- Acquisition of electronics for the X-ray BPMs (Beam Position Monitors) in the beamlines
- Hiring of 5 technicians to enable the machine to be attended to in three operational shifts.

2.3 Consolidating SESAME's infrastructure serving the machine and beamlines

The machine and beamlines may only operate well if the infrastructure required for them is in place. This point therefore outlines what would be needed for this.

2.3.1 Installation of a liquid nitrogen station

Liquid nitrogen is needed on a regular basis for the cryogenic systems, superconducting magnets (once in place), and all the experiments at the BM02-IR beamline and some of those at the BM08-XAFS/XRF and ID09-MS/XPD beamlines, yet the nearest commercial outlet from where it may be purchased is located about 35-40 km from SESAME. This makes using this outlet not only impractical but also costly both because of the transportation costs involved and also because during transportation a great deal of the liquid nitrogen is lost through evaporation. The solution is therefore the installation of a liquid nitrogen station on the premises of SESAME.

2.3.2 Preparation of the infrastructure for the ChemLab, BioLab, MatLab

Services and installations such as the supply of water, gas and deionized water, sinks, fume hoods, benches, shelves, storage cupboards for chemicals, refrigerators, and waste containers are required for the ChemLab, BioLab and MatLab to be set up by the Scientific Sector. Responsibility for this infrastructure falls on the Administrative Sector, and it would need to be put in place before procurement of the laboratory equipment.

2.3.3 Earthing of SESAME's building, machine and beamlines

For the safety of the staff and SESAME's building and facilities, as well as the proper functioning of the latter, earthing of all the laboratories, the machine and beamlines is mandatory. Part of the earthing system is, in fact, already installed, however, this is not the case for all the laboratories, parts of the machine and the beamlines, and normalizing this situation needs to be given the highest priority in order to avoid any possible accident.

2.3.4 Renovation of the staff's computers

Having modern computers is very important both for the installation of updated software and to avoid loosing important data as a result of the crash of a hard drive or another similar incident. Yet the computers of the majority of the staff are old. The plan, therefore, is that henceforth each year the computers of 25% of the staff will be replaced by newer versions so that the full set of SESAME's computers are renewed once every four years.

2.3.5 Upgrading and development of the Information Technology (IT) infrastructure

As the foundation of an organization's technology systems, SESAME's IT (information technology) infrastructure (e.g. servers, switches, storage, etc.) would need to be robust, state of the art and in good working condition. Therefore, SESAME's IT staff would need to elaborate a plan for regularly upgrading and developing the infrastructure and maintenance work, and this plan would need to be regularly updated and rigorously followed.

2.3.6 Renovation of SESAME's main building

The main SESAME building was inaugurated in 2008, that is, almost 15 years ago. This means that it is now time to carry out renovations and maintenance work if it is to continue functioning properly and not fall into disrepair. The works involved would be the water supply system, sewage system, electrical system, insulation of the roof, and painting of the walls. These works, which will be funded from the operational budget, should start at the latest in two years' time.

3- Objectives of the Five-Year Strategic Plan

3.1 Scientific priorities

3.1.1 Science vision

Although planning and building large-scale research infrastructures like synchrotron light facilities takes time, their operating phase lasts for decades. This inevitably implies careful planning and long-term thinking to enable the desirable expansion of the infrastructure and its adaptation to the shifting scientific landscape and technological advancements.

SESAME provides a combination of varied complementary instruments for investigating material characteristics at scales ranging from angstroms to several centimetres, which is something unique in the region. In addition to being a source of excellent scientific contributions to short-term goals, the experimental opportunities SESAME offers help build up knowledge that can contribute to solving big problems over extended periods. The Centre's operation and future growth will therefore be primarily motivated by global challenges related to food and health to energy storage and green hydrogen, clean water, advanced materials, and the design of catalysts. Given the geographical location of the Facility, due emphasis will be given to cultural heritage applications.

Open to users since 2018, SESAME now has a growing user community exploiting its three operational beamlines. Two additional beamlines, both fully funded by Europe, the European Union in the case of the ID10-BEATS beamline, and the Helmholtz Association of German Research Centers in the case of the ID11L-HESEB beamline, will soon also be at the service of users, thereby bringing to five the total beamline portfolio. A sixth beamline, the ID11R-TXPES beamline funded by the Presidency of the Republic of Türkiye, has started to be built. That SESAME is now operational with a critical mass of beamlines, that its publications record is what may be expected from a starting facility, that a large prevalence of the authors are from the region, and that the region is starting to construct its own beamlines, is testimony to the need to strengthen the Facility's position as a healthy hub of scientific excellence in the Middle East and beyond, and to reinforce its collaboration with other light source facilities worldwide, in particular with the AfLS (Africa Light Source).

3.1.2 Upgrading the present beamlines

As underscored in section 2.1 above, the first and most urgent need is to consolidate the existing scientific capabilities. This will include setting up support infrastructures (a ChemLab, BioLab and MatLab, the latter also being a first step towards an MX beamline at SESAME), developing a pool of sample environment devices for *in-situ* measurements at all the beamlines, and upgrading the three beamlines already in operation.

3.1.3 Future beamlines

The plan for the Phase 1 beamlines was elaborated subsequent to a thorough consultation with SESAME's prospective user communities. The Scientific Advisory Committee of SESAME, and the now defunct Beamlines Advisory Committee, prepared and validated a list of seven beamlines that reflected the key thematic areas relevant to the Members and their priorities in research and capacity building. These beamlines were the following: (i) IR (Infrared) spectromicroscopy, (ii) XAFS/XRF (X-ray Absorption Fine Structure/X-ray Fluorescence) spectroscopy, (iii) PD (Powder Diffraction), (iv) PX (MAD Protein Crystallography), (v) SAXS/WAXS (Small Angle and Wide Angle X-ray Scattering), (vi) EUV (soft X-ray and Extreme UltraViolet) between 100 and 1600 eV, and (vii) VUV (Vacuum UltraViolet) spectroscopy between 20 and 1000 eV.

Three of these beamlines, those related to infrared spectromicroscopy, X-ray absorption fine structure/X-ray fluorescence spectroscopy and powder diffraction, are now operational. They are the BM02-IR, BM08-XAFS/XRF and ID09-MS/XPD beamlines. The soft X-ray and extreme ultraviolet energy range is covered by the newly-installed HESEB beamline, that will in the near future be complemented by the TXPES beamline.

The plan was subsequently modified to include a tomography beamline.

The soft X-ray beamline, namely the ID11L-HESEB (HElmholtz-SESAME Beamline for soft X-rays) beamline being funded by Germany enables advanced photoemission/spectroscopy experiments and has applications in the fields of health sciences, photonics, advanced materials, environmental sciences, nanostructures, petrochemistry and energy. It has been opened to users in the second 2023 call for proposals, for which the deadline for the submission of applications is 15 September 2023. The Turkish soft X-ray PhotoElectron Spectroscopy beamline, the ID11L-TXPES beamline which is currently under construction, will share the undulator source with HESEB, and with its photoelectron spectroscopy experimental setup completes the equipment foreseen in Phase 1 for a beamline dedicated to soft X-ray and extreme ultraviolet.

The tomography beamline, namely the ID10-BEATS (BEAmline for Tomography at SESAME) beamline, is one in which relatively new user communities in the region showed interest. This was particularly the case of the cultural heritage and archaeology communities. Construction of the beamline is being funded through the European Horizon 2020 programme to the order of €6 million in a project set up to design, procure, construct and commission a beamline for hard X-ray full-field tomography at SESAME. The project was completed in June 2023. This beamline, too, has been opened to users in the second 2023 call for proposals, and again the deadline for the submission of applications is 15 September 2023.

The final three Phase 1 beamlines are expected to be dedicated to MX (Macromolecular/protein crystallography), SAXS/WAXS (Small-Angle and Wide-Angle X-ray Scattering), and VUV (Vacuum UltraViolet) spectroscopy as originally planned.

3.1.3.1 MX beamline

MX is of high priority for SESAME since by offering research opportunities in structural biology and macromolecular crystallography it will raise the level of scientific research in the Middle East to one of high prestige that would rank it as world-class. Most of the current discoveries in medicine related to structural biology are to be attributed to recent developments in synchrotron radiation and its applications. A recent important example is how most synchrotron radiation facilities joined forces to face the coronavirus pandemic and offered their capacities to the global scientific community. In order to prioritize research on the SARSCoV-2 virus, its treatment, and the discovery of a vaccine, many facilities promoted quick-access pathways to dedicated beam time in order to reduce the time span between the submission of proposals and the dissemination of results. The initial design of SESAME's MX beamline is to be modified to take account of changes in the structural biology landscape brought about by the increased use of cryo electron microscopy as a powerful alternative to crystallography, and the capabilities of AI (Artificial Intelligence) networks in solving a protein's 3D shape from its amino-acid sequence.

3.1.3.2 SAXS/WAXS beamline

SAXS (Small Angle X-ray Scattering) is a well-known tool to study the structure of different objects in the range of 1 to 1000 nm, and most synchrotron facilities offer instruments dedicated to these kinds of experiments. With the addition of a WAXS (Wide-Angle X-ray Scattering) detector, diffraction patterns in the range of 0.1 to 0.9 nm can be tracked at the same time. When designing the parameters of this beamline account will need to be taken of technical constraints, but also user-friendliness and reliability, as well as the ability to optimize the distance between the sample and the detector. In addition, the sample positioning area will be designed in such a way that, in addition to the standard set up, users will have the possibility of installing their own sample equipment there.

3.1.3.3 VUV beamline

A vacuum ultraviolet beamline that uses a bending magnet as a source and has an optical layout designed for an extended energy range, from the near-visible at about 3 eV to soft X-rays around 1600 eV, also offering the possibility of choosing the degree of ellipticity, and coupled with an end station that has a wide range of scattering geometries in a UHV (Ultra High Vacuum) environment, would allow exploration of electronic and magnetic properties in conjunction with the structural analysis of solid samples, surfaces, and interfaces. A wide-range, low-energy beamline such as this could provide a variety of spectroscopic methods for investigating the basic features of electronic states in solids by measuring optical absorption, reflectivity, and photoemission yield in a UHV environment. A photon beam with energy spanning from UV to soft X-rays offers a wide variety of possibilities for the combined exploration of a system's electronic and structural aspects. The functions of the beamline would also include determining the performance of optical elements (such as mirrors and multilayers), optical devices, and detectors. A mobile hemispherical electron analyser and a series of photodiodes in the UHV end station would allow angle-resolved photoemission spectroscopy, optical reflectivity, and fluorescence yield measurements. Measurements in the VUV range to measure the photoelectron yield would also be a precious tool to characterize materials in the aerospace sector.

An example is the Emirates Lunar Mission which will send a lunar rover to the moon to study the behaviour of lunar dust exposed to solar irradiation. The rover's materials will be subject to photoelectric effects that are yet to be quantified and measurements have been run for this purpose at the BEAR beamline at the ELETTRA synchrotron facility in Italy, which provides photons with energies between 3 to 1600 eV. Considering the development of the space sector in the Middle East and the usefulness of characterizing materials in irradiation conditions similar to the space environment, the presence of a VUV beamline at SESAME would offer significant advantages.

The SESAME staff, the SESAME user community, and SESAME's Scientific and Machine Advisory Committees will work together to identify which additional beamlines to propose for SESAME. They will carefully consider the scientific importance and technical feasibility of the proposals put forward, their performance on a greatly-upgraded machine with top-up injection, the likely degree of productivity of each and the size of the related potential user community, their priority for the Members of SESAME, and costings.

3.1.3.4 Training activities to support the development of Synchrotron Radiation (SR) in Africa

SR (Synchrotron Radiation) facilities are now the instruments that have the highest impact on cutting-edge research. They are used across an exceedingly-wide range of disciplines, and their output in terms of research is vast. They also have a significant impact on the training of graduate students and technology innovation. SESAME should be a model for SR projects in Africa and Central America, such as the AfLS, the Mexican Synchrotron, and the Great Caribbean-Central American Synchrotron. New large-scale research facilities such as these will address critical multidisciplinary challenges. They can very significantly contribute to capacity building, the promotion of scientific and technological excellence, the construction of scientific and cultural bridges between diverse societies, the development of local innovative competitive industries, and the prevention and reversal of the scientific brain drain. Indeed, in the coming years, access to a local SR source will be a prerequisite to compete socially, politically, and commercially.

Africa is currently the only continent without an SR source. Access to training and education for students and researchers across the continent is critical for the growth of the AfLS.

During the years of its construction, SESAME received very substantial generous support in the form of training opportunities from facilities worldwide. It now has the chance to take the lead in training, in particular for African countries. This prompted it to be the first synchrotron radiation Facility to sign a Memorandum of Understanding with the AfLS Foundation and it is actively collaborating with the IAEA, ICTP (Abdus Salam International Centre for Theoretical Physics), LAAAMP (Lightsources for Africa, the Americas, Asia, Middle East and Pacific) and some LEAPS (League of European Accelerator-Based Photon Sources) facilities in online AfLS training programmes.

3.2 Technical priorities

Since SESAME started hosting users in July 2018 its user community has been growing and the number of its beamlines increasing. This makes many improvements and upgrades to the machine necessary.

The major long-term upgrade foreseen for the machine is the replacement of the current 800 MeV injector with a full energy injector, that is a 100 MeV Linac and a 2.5 GeV booster synchrotron that allows top-up injection. Once in place, this will increase the beam availability for users, and will offer a better beam stability for the beam, better thermal stability for the machine and beamlines, and constant current in the machine. It will also allow the machine to serve a wider spectrum of scientific research by offering different electron-filling patterns in the storage ring.

This full energy injector project as a whole goes beyond the scope of this 5-year plan. What is planned during the forthcoming five years is the replacement of the classical microtron with a 100 MeV Linac, which is the first step towards a full energy injector.

The objective behind these improvements and upgrades is to bring about:

- Higher reliability and better performance of the machine, greater beam availability, longer MTBF

(Mean Time Between Failures), and shorter MTTR (Mean Time To Repair).

- Enhanced machine capabilities and a user facility that permits a wider spectrum of experiments.
- Continued and improved beam stability.
- Expanded technical capabilities.

3.2.1 Higher reliability and better performance of the machine

3.2.1.1 Completing refurbishment of the injector

3.2.1.1.1 Refurbishment of the microtron actuating motors

Since the modulator of the microtron was replaced with new solid-state modulators at the beginning of 2023, the DC actuating motors system is the only part of the microtron still needing to be replaced. These motors are with non-reproducible motion and unreliable encoders which makes it difficult to finetune the motor-dependent parts of the microtron such as the electron gun, magnetron frequency and deflection tube. They need to be replaced with modern and reliable ones.

3.2.1.1.2 Refurbishment of the booster pulsed elements

The **booster injection septum** is an electrostatic septum with a 100 kV/cm input voltage at 20MeV beam energy. It suffers from a residual lower-level instability, and this is reducing the average injection efficiency into the booster which, in turn, results in longer filling time for the storage ring and asymmetric filling for the bunches. This instability has recently been greatly mitigated following the improvement made to the insulation of septum's transformer which reduced the ring's filling time by a factor of two. There nevertheless remains more refurbishment of the septum needed in terms of electronics.

The **booster extraction kicker** is generally speaking in good shape, but it needs some improvement such as *inter alia* installing a new enclosure for its switch box. Its cables have already been replaced by new, more suitable ones, however, there remain some mechanical deficiencies in terms of feedthroughs and connections which result in shortages in the kicker's performance and a lower efficiency of the beam extraction from the booster. Refurbishment of the kicker needs to be continued to improve the beam extraction from the booster and reduce the filling time of the storage ring. There is also a need to refurbish the kicker's power supplies.

The **booster extraction septum** is in a good shape; however, its power supply needs to be refurbished for more reliable performance.

3.2.1.2 Replacing the microtron with a 100 MeV Linac as a long-term solution

As mentioned above, the ongoing refurbishment of the microtron is the proper short-term solution to keep it running in a reliable manner and ensure its good performance for a longer time. The long-term solution is to replace the microtron by a 100 MeV Linac. A Linac offers several advantages over a microtron for a third-generation light source like SESAME. In addition to the higher current it delivers (and consequently faster filling for the storage ring) and the lower complexity of its operation, it will offer the possibility of having different filling modes for the storage ring, an advantage that will allow the SESAME machine to serve a wider spectrum of scientific research. Another important consideration is the fact that use of a Linac as a pre-injector is something common to virtually all synchrotron light facilities, which makes spare parts more easily available, and means that there is a wealth of technical experience in the accelerator community from which SESAME may benefit. The installation of a 100 MeV Linac will be the first part of SESAME's future full energy injector.

3.2.1.3 Securing all spare parts needed for the machine

Procurement of spare parts for each of the machine operation-related devices or components is a must to increase the reliability of the machine and the availability of the electron beam. This will reduce the MTTR (Mean Time To Repair) and hence increase the beam availability for users. Due to SESAME's very limited budget, many systems are still missing spare parts and some, such as those for the RF and cooling systems, are critical. There are some spare parts being secured, but this is happening at a very slow pace that is subject to the budget and donations from different laboratories and institutions.

3.2.1.4 Upgrading the Radio Frequency (RF) system

Upgrading the power transistors

SESAME's RF system is using cutting-edge technology in terms of SSAs (Solid-State Amplifiers) and LLE (Low Level Electronics). However, the power transistors used in the SSA modules are becoming obsolete since the company producing them has started production of a new line of transistors (BLF598) and it will be stopping to produce those on SESAME's SSAs. SESAME has been sent two samples of this new line for testing and evaluation and it found that they performed better than the power transistors that it was using. There was, however, one drawback. This was that using the new line would necessitate some modifications to the hardware of the SSA modules. SESAME's RF team has therefore consulted RF teams in other facilities (e.g. SOLEIL) on the required modifications.

Calibration of the directional couplers

The RF waveguides and the corresponding directional couplers had been donated to SESAME and are not new. The waveguide directional couplers, whose output reading is used by the LLE for regulating the feedback loop, need to be calibrated to a new reference coupler which will help LLE more accurately control the RF system, and consequently perform better.

3.2.1.5 Upgrading the cooling system for improved performance

The cooling system needs to be upgraded for better performance and more reliability. The upgrading requirements are defined as follows:

Understanding the system behaviour for better management of the water distribution

There is a great need for a simulation code to understand the system behaviour and obtain a clear figure of the current water flow distribution. This will help better manage the water distribution in the operational cooling network and achieve more optimized performance. SESAME does not have such a code and needs to obtain one.

Improving the monitoring system, and having better water distribution on the consumption side of the cooling system

The cooling system is missing good monitoring of the different parameters such as water pressure, temperature, and the good control of the distribution of the water flow. This system needs to be improved by adding many pressure gauges, and temperature sensors, as well as strainers and regulations valves as seen in more detail in chapter 4.

Improving the ventilation and monitoring systems, and achieving better water quality on the production side of the system

The water quality needs to be continuously monitored and controlled in order to keep the high electrical insulation property of the water and not to harm the copper cooling pipe network. This implies the installation of many pH, oxygen and conductivity sensors. Moreover, the air bubbles in the water make interlocks in the water flowmeters and trip the machine from time to time. Hence the ventilation system in the cooling network needs to be improved.

Reducing the stress on the storage ring pumps

The storage ring pumps are running at the limit of their frequency load in order to keep a sufficient water flow rate in the storage ring. This mode of operation is not recommended and it is a source of stress on the pumps. This problem needs to be solved.

Improving performance of the Air Handling Unit (AHU)

The AHU (Air Handling Unit) has an insufficient number of temperature sensors with unbalanced distribution. Consequently, there is a noticeable variation in the air temperature in the experimental hall. Improving the quality and distribution of the network of the temperature sensors is required for a better control of air temperature in the experimental hall.

Recommended acquisition of a spare chiller

The water is cooled by two chillers which are running throughout the operation of the machine and there is no spare chiller available. The installation of a spare chiller is therefore recommended to avoid failure of one of the existing two from bringing the machine to a halt until repairs have been carried out on the faulty one.

Recommended acquisition of a third heat exchanger

There are only two of the three heat exchangers available. Although calculations show that two can support the design current of 400mA, the acquisition of a third is needed as a spare one in case one of the two operational ones is interrupted or undergoing maintenance.

Upgrading the Building Management System (BMS)

The BMS (Building Management System) control in use has many weak points, namely:

- Most of the cooling system data cannot be archived, hence their history is lost.
- BMS cannot be integrated into SESAME's EPICS (Experimental Physics and Industrial Control System) system.
- The controllers in use are obsolete.
- There are no electrical drawings available for the existing control panels.
- The controllers cannot be accessed by SESAME's control team. Hence, the team is unable to perform any investigation, maintenance or upgrade.

This means that the current system needs to be upgraded or completely replaced with another control system based on PLC (Programmable Logic Controllers) in which the SESAME control team has good experience.

Upgrading the air compressed system

The compressed air system has two ZT15 compressors each having an air delivery of 30.1 l/s. The system is running at 45 l/s, that is at 75% of its maximum capacity. This means that both compressors run simultaneously, and one compressor alone would be unable to deliver the full air pressure required by the machine. Hence, in the case of the failure of one of the two the machine pneumatic system would stop, and so consequently would the machine. The reason for this high air consumption is the open-air circuits used for cooling the RF couplers, the IR beamline and some of the other beamlines, in addition to the consumption by those laboratories that use the compressed air for blowing up works. SESAME needs to be in a position where one compressor only is able to deliver the air pressure required by the machine while the second may be in standby mode. As is, the present compressors can be a single point of failure for the machine and should be replaced with ones having a larger capacity of air delivery.

3.2.1.6 Upgrading the control system

Upgrading the Programmable Logic Controllers (PLCs)

The PLCs (Programmable Logic Controllers) in use at SESAME are SIEMENS s7-300. In 2023, production of this series was stopped, and the manufacturer replaced this by another series, namely s7-1500 PLC. However, spare parts for the former will still be available for many years to come, but there will no longer be any technical support provided. Consequently, SESAME's system should be upgraded to the new version before that it is using becomes obsolete and there is no technical support for it.

Installation of security boxes for the absorbers and beamlines

The water flow switches in the ring do not indicate whether the flow is at, or below, the set value, and this is occasionally a source of machine interlocks. Installing security boxes, which will result in the flow status being available in the ring, will greatly facilitate calibrating the flow switches of the absorbers or beamlines. Moreover, this will make adjusting the switch interlock level easier, faster and less labour intensive.

Upgrading the Personnel Safety System (PSS) and Equipment Protection System (EPS) racks

Due to the increasing number of signals, more modules will need to be added to the PSS (Personnel Safety System) and EPS (Equipment Protection System) PLCs which need to be upgraded to host racks.

Upgrading the Linux Operating System (OS)

The current OS (operating system) for the control servers is Centos 7. This system will reach the end of its life on 30 June 2024. It will therefore need to be replaced, and this should be done by a more modern OS.

3.2.1.7 Upgrading the diagnostics system

Building an X-ray pinhole camera

The existing diagnostics beamline uses the visible light emanating from the dipole source. Monitoring the beam performance and beam instabilities through monitoring of the transverse beam size is indispensable. However, for a more precise measurement of the beam size and transverse emittance, as well as more sensitivity in monitoring beam stability, a better resolution (better than few microns) for measurement of the beam size is needed. This is being ensured by the installation of an X-ray pinhole camera which is widely used as a result of the simplicity of its structure and high reliability.

Equipping the remaining Beam Position Monitors (BPMs) with Libera processors

The storage ring contains 64 BPMs (Beam Position Monitors) (i.e. 4 BPMs/cell) to be used in closed orbit correction. However, due to the limited budget, only 48 of them are equipped with Libera Brilliance plus electronics to correct the orbit at the most critical locations. Moreover, only 32 of these 48 BPMs are equipped with the fast data acquisition GDX (Gigabit Data Exchange) modules. But the growing number of beamlines and the need for a fast orbit feedback system makes it necessary to equip more BPMs with Libera electronics and GDX modules.

Ability to measure the filling pattern in the storage ring accurately

The filling pattern in the storage ring is currently measured using an FCT (Fast Current Transformer), that is, a measurement which is limited by the electronic noise in the device and does not give a precise reading. A more accurate measurement would be one carried out with the TCSPC (Time Correlated Single Photon Counting) system which is based on measurement of the temporal distribution of the produced synchrotron radiation using Electro-Optical devices. A precise measurement would enable a clean and exact filling pattern in the ring that satisfies the requirements of time-resolved experiments.

Installing X-ray Beam Position Monitors (XBPMs) in some of the beamlines

The XBPM (X-ray Beam Position Monitor) (or photon BPM) is the first real diagnostics tool for the photon beam in the beamlines. It is capable of decoupling beam instabilities and fluctuations originating from the storage ring from those originating from the beamlines, which makes it an important device when trying to pinpoint the source of a photon disturbance. Additionally, it can be used to cross check the readouts of the ring BPMs, and can possibly be included in a closed loop orbit correction as a feedback tool.

Increasing Beam Loss Monitors around the storage ring

Increasing the number of detectors around the storage ring will help understand the mechanism of beam losses and beam performance during injection.

3.2.1.8 Upgrading the power supply system

The control system for the power supplies of the storage ring magnets presently used relies on version 3 of the PSI (Paul Scherrer Institute) controller which uses FPGA (Field-Programmable Gate Array). These controllers are becoming obsolete and are not easy to upgrade or modify. SESAME is currently working on the design and implementation of a new SCE2 (SESAME Control Electronics 2) power supply control system in replacement of the present SCE (SESAME Control Electronics) control system.

3.2.1.9 Increasing the manpower for operation of the machine

The machine operation team needs to be increased by 5 technicians in order to enable the machine to be attended to for three shifts per day. This will reduce the time needed to recover the beam in case of beam loss during the third shift.

3.2.2 Enhancement of the machine capabilities and making it more attractive for a wider spectrum of experiments

3.2.2.1 Pushing the stored beam current towards the design value of 400 mA

An important element in synchrotron light sources is the high brilliance of the photon beam delivered to the experiments. The brilliance is directly proportional to the beam current value. SESAME's stored operational electron beam is now 300 mA while the design one is 400 mA. Pushing towards 400 mA would increase the photon flux which would be a good achievement. However, there is first a need to be sure that increasing the current above 300 mA would not push the RF system to its operation limit as a result of the higher RF power required. Should this be the case, increasing the current will be postponed to a future date when the RF system is upgraded in terms of the maximum RF power that may be delivered, but this goes beyond the scope of this Strategic Plan.

3.2.2.2 Offering various filling patterns in the storage ring

The only filling pattern SESAME's machine can offer is the multi bunch one. It is unable to offer any other filling pattern such as single bunch or hybrid modes due to the pre-injector in use, which is a classical microtron with a fixed electron pulse length of 1.5 μs. Offering various filling patterns in the ring would enable other types of experiments to be served by the SESAME machine. An example would be time-resolved experiments.

3.2.3 Maintaining and improving the beam stability

3.2.3.1 Multi Bunch Feedback (MBF) system

The MBF (Multi Bunch Feedback) system is needed to dump any beam multi bunch instability which is mainly a current-based one. The need for a higher stored beam current and the increasing number of insertion devices with low gap chambers may require the continuous use of the MBF system. Moreover, a LMBF (Longitudinal Multi Bunch Feedback) system will also be needed to dump longitudinal instabilities, and for this there will be a need to install a cavity kicker in the ring.

3.2.3.2 Fast Orbit FeedBack (FOFB) system

Although the disturbance created by the HESEB Apple II undulator is to a great degree compensated by the feed forward tables, a FOFB (Fast Orbit FeedBack) system may nevertheless be needed for any fine residual disturbances that cannot be treated through the feed forward tables. There will also be a need to dump any fast disturbance to the beam that may originate from any distortion sources.

3.2.4 Expanding the technical capabilities at SESAME

3.2.4.1 Securing the required laboratory equipment and measurement tools

There is a need to furnish the technical laboratories with all the equipment and tools needed for measurement, testing and development works. This will help the staff implement more development projects, which in turn will improve the performance of the machine.

3.2.4.2 Establishing a magnetic measurement laboratory

SESAME needs to increase its experience and capacity in magnetic design and measurement to the level of that of other light sources. Hence establishing a magnetic laboratory would be very helpful for increasing such experience and building such capacity.

3.3 Administrative priorities

3.3.1 Operation and maintenance of the Solar Power Plant (SPP)

The contract drawn up with the constructor of SESAME's SPP (Solar Power Plant) included the 5-year operation and maintenance of the plant free of charge. This five-year period comes to an end in February 2024. SESAME will therefore have to decide to whom it is to entrust responsibility for the operation and maintenance of the SPP with effect from March 2024.

3.3.2 Construction of an administration building

SESAME's main building, which was completed in November 2007, is a two-storey building with the experimental hall at its centre. The ground floor opens directly onto the experimental hall which, together with the shielding wall, occupies most of the footprint area. The remaining area consists of rooms that serve as workshops, laboratories, and, in a few cases, storage rooms for equipment. There are no offices on the ground floor. They are all on the upper floor (first floor), where the space is shared with the large room for the IT servers, and meeting rooms of varying sizes.

The staff of all the sectors, as well as those from the Director's support offices, have an office on the first floor. As SESAME's programme expands and the work generated by the increase in the number of users and beamlines rises, this office space becomes too small to accommodate all the staff. This makes construction of another building for the staff badly needed.

3.3.3 Installation of an Uninterruptable Power Supply (UPS) and diesel generator for the security system and emergency lights

SESAME is running on electricity from the local national grid of Jordan. Electricity generated by the solar power plant is fed to the grid at the production site (about 35 km away). SESAME withdraws its needs in electricity from the grid, and a balance is credited/charged to SESAME at the end of each month.

Although a dedicated line connects SESAME to the power station, SESAME still suffers from some instability in the electricity supply and some occasional blackouts.

The IT infrastructure, such as servers and switches, is protected for 30 minutes by a UPS (Uninterruptable Power Supply) and for a few hours by a diesel generator separate from the rest of the building electricity network. In case of a blackout the IT engineers are alerted on their cell phones to take action. This keeps the system in a safe condition.

SESAME's security system, gates, fire alarm system and fence and street lights are directly connected to the building electrical network. Therefore, none of these systems would work when there is a blackout, which would make SESAME's installations vulnerable to misuse or sabotage. It would also put SESAME in a dangerous situation in the event of a fire that starts while the fire alarm system is down.

3.3.4 Renovation of the fire alarm system

One of the earliest emergency systems to have been installed at SESAME was the fire alarm system. Part of the system was damaged in 2013 when the roof collapsed, and the system was reinstalled after construction of the new roof. Added to this, the alarm system is outdated, and spare parts are no longer available on the market. The result is that there have been a number of times in the past when the system gave a false alarm. Moreover, there are some sections that are not working. For instance, although the alarm is meant to go off in the guards' room at the main gate, this has not been happening for years already.

Furthermore, the fire alarm system is not connected to the machine tunnel which has a separate system connected to the control room. Thus, if fire were to start in the tunnel when the machine was not working and there was no operator in the control room, the alarm system of the building would not be triggered until the smoke had reached the smoke detector beams of the experimental hall.

4 - Plan to Achieve Objectives

4.1 Advancing the Scientific Sector

4.1.1 Beamlines and other facilities

The ChemLab facilities must include a glovebox, fume cupboard and bench-top space. Standard laboratory equipment (such as a pH-meter, deionized and ultrapure water, stirrers, balances, an extensive stock of glassware, glove bags, refrigerator/freezer, ice machine, furnaces, ultrasonic bath) and frequently used solvents/chemicals/consumables also need to be made available.

The BioLab will be equipped with a laminar flow hood, a chemical hood, an autoclave, an ice machine, a table-top centrifuge, a dishwasher, refrigerators (-20 °C and 4 °C), various pipettes and tips, precision and analytical balance, and pH meter, and a water processing unit for pure and ultrapure water.

The primary tasks of the MatLab will be cutting, polishing and sectioning samples, building customized sample or detector supports such as frames and cells, and observing and mapping the samples' area of interest by means of an optical microscopy. The needed equipment includes a milling machine, lathe, drill press, rolling mill, spot welder, inverted optical microscope with micromanipulator, spark eroder, cryomicrotome, and polishing machine.

At the IR beamline it is necessary to increase the number of degrees of freedom of the elements of the optical system, as well as the diagnostic tools. This will allow full utilization of the source, and ultimately an increase of the beam intensity for the experiment.

For X-rays, energies are selected using the diffraction in a crystal, typically a slab of Silicon cut along a low-index crystallographic plane. If the X-rays impinging on the monochromator are all parallel to each other, the energy resolution is limited only by the angular width over which the diffraction occurs. This is called the Darwin width and depends on the crystal diffraction used and on the wavelength. If the divergence of the beam is larger than the Darwin width of the monochromator, then it will be this divergence that will be the factor limiting the energy resolution. Typical values for the angular acceptance of an X-ray beamline are one order of magnitude larger than the Darwin widths of commonly-used crystals. A cylindrical mirror before the monochromator, collimating the beam in the diffraction plane to below the Darwin width is the commonly-utilized means to obtain a parallel beam and the highest energy resolution for a given monochromator. The fact that the first mirror of the XAFS/XRF beamline is flat and not collimating the beam - it never has done so since its bending mechanism is not working - is lowering the performance of the beamline by a factor 30. Moreover, the absence of a focusing mirror after the monochromator - although foreseen in the beamline design - makes it necessary to reduce the beam size by cutting part of it by the use of slits, instead of concentrating it in the focus of a mirror, and this results in a further loss of flux. The combined effect of the absence of the two mirrors reduces the photon density at the sample by almost three orders of magnitude, which calls for immediate investments in beamline optics.

Time-resolved research in powder diffraction is hampered by the lengthy duration needed to record spectra by relocating the diffractometer's 2 theta arm. A fixed microstrip system that uses a single X-ray detector to cover a broad area has in recent years become the standard solution in powder diffraction beamlines worldwide. This will represent an effective and necessary upgrade for the MS/XPD beamline of SESAME.

4.1.2 Staff needs in the Scientific Sector

The beam time available at a beamline is a combination of the time dedicated to maintenance and upgrading of the instrumentation and the time available for user experiments. To successfully manage work at facilities that generally work round the clock, seven days a week, and bearing in mind that at least one scientist needs to be either present at each beamline or available on call, beamline teams typically consist of three to five scientists in different stages of their career, plus some technicians and engineers. Ten-person teams are therefore not uncommon. At SESAME, where the user community is still not very familiar with synchrotron radiation techniques and needs help for the analysis and interpretation of data, the workload on the beamline scientists is even heavier than at mature facilities. Until now, few positions have been opened to recruitment, and this situation has been aggravated by the mediocre quality of the candidates having applied for them. It is thus critical to open new posts for beamline scientists as soon as possible so as to increase the number of scientists per beamline to at least three. The increased number of beamlines also implies that SESAME will need to appoint more staff to the pool of beamline technicians and to the Detectors and Electronics, the Scientific Computing and Systems Communication, and the Data Collection and Analysis teams. Similarly, new positions for technicians and other back-up staff will need to be created once a ChemLab, BioLab and MatLab have been put in place.

4.2 Developing the SESAME machine

4.2.1 Higher reliability and better performance of the machine with higher beam availability, longer Mean Time Between Failures (MTBF), and shorter Mean Time To Repair (MTTR)

In order to achieve higher reliability and better performance of the machine and greater beam availability, as well as longer MTBF (Mean Time Between Failures) and shorter MTTR (Mean Time To Repair), in the short term, there is a need to completely refurbish the injector system and, in the long term, to replace the microtron with a 100 MeV Linac. In the short term, too, there is also a need to secure all the required spare parts for the machine, and to upgrade the RF, cooling, control, diagnostics and power supplies systems, as well as to increase the manpower for operation of the machine.

4.2.1.1 Complete refurbishment of the injector system (Microtron and Booster)

a) Refurbishment of the microtron actuating motors

The actuating motors in use, which will be the only part of the microtron still needing to be replaced, are with non-reproducible motion and unreliable encoders. Hence, they need to be replaced with more accurate stepper motors and more reliable encoders.

b) Refurbishment of the Booster pulsed elements

Overall, the booster synchrotron is in good shape, however there are some parts that need to be refurbished to improve its performance. This is the case of the pulsed elements, namely the injection septum, injection kicker, extraction kicker, and extraction septum.

i. Booster injection septum:

The lack of isolation in the injection septum transformer box has been a source of problems, however this has now been mitigated by replacement of the transformer box with a Faraday cage. There nonetheless still remains a need to refurbish the injection septum switch box.

ii. Booster injection kicker:

The switch box of the injection kicker needs a new enclosure. The enclosure has already been designed, but it needs to be manufactured.

iii. Booster extraction kicker:

The extraction kicker feedthrough needs to be replaced with new ones and to do this there is a need to disassemble the kicker of the Booster. Moreover, the kicker power supply needs to be refurbished and its rack to be replaced by a new one, and it is expected that 8-10 months will be needed for this.

iv. Booster extraction septum

The power supply of the extraction septum needs to be refurbished.

4.2.1.2 Replacing the microtron with a 100 MeV Linac as a long-term solution

The 100 MeV Linac that is to replace the microtron will be a compact one that is 8.2m in length and uses only one high gradient accelerating structure as in the case of that adopted for the Fermi Linac at Elettra. The reason for this is the lack of sufficient space inside the shielding wall of the booster for a traditional 100 MeV Linac, which would be ~13-14m long. All specifications of the compact Linac have recently been drawn up, and immediately the required budgetary resources are available, a tender for construction of the Linac will be issued.

4.2.1.3 Securing all the spare parts needed for the machine

The plan is to first and foremost secure all the critical spare parts without which the performance of the systems for which they are needed could be very adversely affected. In the case of small-sized consumables such as electronic parts, there will be a reserve stock of 10%. Given the limited budget available, procurement of the spare parts has been prioritized.

4.2.1.4 Upgrading the Radio Frequency (RF) system

a) Upgrading the power transistors

The plan for the coming years is to define the modifications that need to be made to the hardware of the SSA modules so that it is compatible with the new line of transistors now being produced (BLF598), and to then gradually move to these new transistors by replacing any failed transistor by a BLF598 one. In parallel, efforts will be made to secure as many transistors as possible of the type SESAME is currently using.

b) Calibration of the directional couplers

Although of low priority in the upgrading plan, to have a new directional coupler as a reference coupler for calibrating the four existing ones would be very helpful.

4.2.1.5 Upgrading the cooling system for improved performance

In order to achieve better performance and more reliability, the cooling system will be upgraded in the manner outlined in points (a) to (i) below.

a) Understanding the system behaviour for better management of the water distribution

Software will be purchased for the simulation needed to understand the system behaviour for the better management of the water distribution. This need not be an expensive software, and Flow Expert software will be more than satisfactory.

b) Improving the monitoring system, and ensuring a better water distribution on the consumption side of the cooling system

The following upgrades are required in order to improve the monitoring system and achieve better water distribution on the consumption side of the cooling system:

i. Electronic pressure gauges (with their accessories) to monitor the water pressure distribution in the network.
ii. An electronic temperature sensor (Pt100 RTD) in the network to monitor the water temperature for more temperature stability.
iii. Replacement of all the flexible hoses of the storage ring magnets.

iv. Replacement of the rigid pipes of the RF connections with flexible hoses for better water temperature stability in the RF cavities.

v. A network of water detection sensors to detect water leakages and stop the cooling system should any water leakage be detected.

vi. Sixteen flow regulation valves at the entrance of the storage ring dipoles for better control of the water flow at each magnetic cell.

vii. Strainers with gate valves for the secondary system inlet and outlet to facilitate the flushing process.

viii. Two open/close valves near the T–Junction in order to manage all the alternative flow distribution in the beamline water circuit.

ix. A Variable Frequency Drive to those pumps that do not have one.

x. Increased instrumentation for the pumping system for more protection of the pumps.

c) Improving the ventilation and monitoring systems, and achieving better water quality on the production side of the system

The following upgrades are required in order to improve the ventilation and monitoring systems and to achieve better water quality on the production side of the system:

i. Degassing equipment for the main water supply in the technical building to extract the air bubbles from the water circuit and to replace the existing ventilators.

ii. Two pumps for the water quality panel in the technical building used for water quality measurement.

iii. Four pH sensors (with their accessories) in the technical building to monitor water quality. The pH sensors should be accompanied by four flow meters.

iv. Two oxygen sensors (with their accessories) in the technical building to monitor water quality. The oxygen sensors should be accompanied by two flow meters.
v. Four conductivity sensors (with their accessories) in the technical building to monitor water quality. The conductivity sensors should be accompanied by four flow meters.
vi. A portable ultrasonic flowmeter to measure the water flow rate.

d) Reducing the stress on the storage ring pumps

The optimal way to reduce stress on the storage ring pumps as a result of their running at the limit of their frequency load will be to replace them with pumps of a larger capacity. The pumps replaced will subsequently be used as spare units for the chiller pumps.

e) Improving performance of the Air Handling Unit (AHU)

In order to ensure a better control of the air temperature in the experimental hall, there is a need to install many air temperature sensors that guarantee a more uniform distribution of the air temperature. In addition, the ventilation windows need to be upgraded.

f) Acquisition of a spare chiller

There is a need to acquire a chiller for the water cooling system so that there is a spare one in the event of failure of one of the two currently in use to cool the water.

g) Acquisition of a third heat exchanger

In the case of the heat exchangers, too, there is a need for a spare one so that it may be used when maintenance is being carried out on one of the two in operation or in the event of failure of one of these two. Moreover, it may even be put into operation to support the two operating ones and thus reduce the load on them since the design number of heat exchangers is three.

h) Upgrading the Building Management System (BMS)

The weaknesses of the BMS (Building Management System) have been studied in collaboration with various service companies and more than one solution has been proposed. The optimum one transpires to be replacement of the BMS system with a control system based on PLC (Programmable Logic Controllers) as this would give the control team, which has good expertise in the latter, full control over it and the system would be easier to modify or upgrade in the future.

i) Upgrading the air compressed system

The most economic solution to avoid the machine coming to a halt due to failure of one of the two current compressors needing to run simultaneously for delivery of the full air pressure required by the machine is to replace the two compressors with compressors of a larger capacity so that one is sufficient for the machine and the second is on standby in the event of failure of the one in operation.

4.2.1.6 Upgrading the control system

a) Upgrading the Programmable Logic Controllers (PLCs)

SESAME will gradually migrate from its SIEMENS s7-300 PLCs (Programmable Logic Controllers) to the new s7-1500 PLC to be manufactured instead. It will do so because production of s7-300 PLCs ceased in 2023, and it should avoid finding itself in a position where no technical support or spare parts are available for its system. It will do this in phases over a number of years based on the funds available. In phase I, it will change all the controllers of the PLCs, and it will do so in 2024 since in that year the manufacturer will cease providing technical support for s7-300 PLCs. In phase II, it will change all the I/O

(Input/Output) modules of the PLCs, and this it will do over a number of years since the manufacturer will have spare parts for s7-300 PLCs for many years to come.

b) Installation of security boxes for the absorbers and beamlines

Many security boxes will need to be installed in the ring to help facilitate the calibration of low switches.

c) Upgrading the Personnel Safety System (PSS) and Equipment Protection System (EPS) racks

More racks will be installed to host the increasing number of PLC modules for the PSS (Personnel Safety System) and EPS (Equipment Protection System) systems.

d) Upgrading the Linux Operating System (OS)

The required upgrading of the OS (operating system) of the control servers from the current Centos 7, which will reach the end of its life on 30 June 2024, to the more modern Rocky Linux version, has already started. It is continuing in 2023 and would need to be completed before June 2024.

4.2.1.7 Upgrading the diagnostics system

An X-ray pinhole camera beamline has been installed in the ring as part of the diagnostics system in order to obtain a better resolution for measurement of the beam size. This has been done in an exceedingly cost-effective way, but the most costly part of the camera is the absorber and due to the lack of funds an in-house customized copper mirror has had to be used for this purpose, and for a better and more reliable performance there is a need to upgrade it to the original design of what would have been the absorber.

Funds also need to be available for the other upgrades required for the diagnostics system, namely procurement of Libera processors for the remaining sixteen BPMs (Beam Position Monitors), a TCSPC (Time

Correlated Single Photon Counting) system, XBPMs (X-ray Beam Position Monitors) for some of the beamlines, and more beam loss monitors to place around the storage ring.

4.2.1.8 Upgrading the power supply system

The new control system for the power supplies of the storage ring, namely the SCE2 (SESAME Control Electronics 2), will be fully built in-house without the use of any FPGA (Field-Programmable Gate Array). This will facilitate any future development at SESAME, including replacement of the present SCE system. It will also be possible to use these control electronics for the control of any future power supplies such as those of a full-energy Booster.

4.2.1.9 Increasing the manpower for operation of the machine

The cost-effective way to increase the number of machine operators is to hire technicians needed in the Technical Sector and to entrust them with dual tasks, namely operating the machine when the machine is in operation and working as technicians in their group in the Technical Sector during shutdown periods.

4.2.2 Enhancement of the machine capabilities and making it more attractive for a wider spectrum of experiments

4.2.2.1 Pushing the stored beam current towards the design value of 400 mA

The present stored beam current of 300mA may be increased up to its design value of 400 mA by expanding the power capacity of the existing RF system. The power capacity of the RF system may in turn be increased by amplifying the output power of the solid state amplifiers and replacing the couplers in use by ones with a larger power capacity. Before increasing the current, there is also a need to check whether the capacity of the cooling system would allow this or whether there is first a need to augment the capacity.

4.2.2.2 Offering various filling patterns in the storage ring

Using a Linac as a pre-injector will make it possible to automatically offer various filling patterns in the storage ring. Thus, until such time as SESAME has a Linac, various filling patterns in the storage ring are only possible after first cleaning the undesired bunches in the ring by means of the Transverse Multi-Bunch FeedBack (TMBF) system. More work needs to be done on the calibration and fine-tuning of the TMBF to achieve efficient and precise bunch cleaning, hence clean filling patterns. Consequently, the TMBF system would need to be upgraded with a fine-tuning system (digital delay line).

4.2.3 Maintaining and improving beam stability

4.2.3.1 Multi Bunch Feedback (MBF) system

Thanks to donations by the Australian Synchrotron, the Canadian Light Source and the Diamond Light Source, SESAME now has a complete TMBF (Transverse Multi Bunch Feedback) system, and this system has already been installed in the machine. From the Brazilian Synchrotron Light Laboratory it has received a longitudinal cavity kicker that may be installed in the ring once the required tapered sections needed to connect it to the chamber of ring straight section are available.

4.2.3.2 Fast Orbit FeedBack (FOFB) system

Work on the requirements of a FOFB (Fast Orbit FeedBack) system has started and will continue so that such a system is in place by 2024. The cost of setting up a FOFB will depend on the performance of the equipment SESAME has available for it, it being understood that the full cost will need to be paid if the system has to be built from scratch.

4.2.4 Expanding the technical capabilities at SESAME

4.2.4.1 Securing the required laboratory equipment and measurement tools

Except in the case of possible donations from friends of SESAME, SESAME will need to have the full budget required for the procurement of equipment and tools needed for its technical laboratories.

4.2.4.2 Establishing a magnetic measurement laboratory

SESAME will undertake steps to start establishing a magnetic laboratory to build up experience in magnetic measurement needed for any magnetic development or future machine upgrades.

4.2.5 Staff needs in the Technical Sector

Bearing in mind the ongoing maintenance and development works, the machine operation needs, the planned upgrades on the machine, the greater technical capabilities required, and the increase in the number of beamlines the following additional new positions will be required in the Technical Sector over the next 2-3 years:

- Controls section: 1 controls engineer
- Electrical engineering and power supplies section: 1 technician cum machine operator
- Insertion devices and magnets section: 1 magnets and insertion device engineer or physicist + 1 magnets and insertion device technician
- Mechanical engineering section: 1 service technician for the mechanical workshop + 1 alignment technician cum machine operator
- Vacuum section: 1 vacuum technician + 1 cooling instrumentation technician cum machine operator

4.3 Developing the administrative infrastructure

4.3.1 Operation and maintenance of the Solar Power Plant (SPP)

SESAME has two options insofar as responsibility for the operation and maintenance of its SPP beyond February 2024 is concerned. The first is to either draw up a contract with the constructor of the SPP (or a similar firm) for continuation of this service for a further 5 years only this time against payment. The second is to take total responsibility for this work itself. In the latter case there will probably be a need to purchase a cleaning machine and to hire three engineers. Which of the two options is eventually selected will depend on the cost estimate, and in either case the required funding will come from the operational budget.

4.3.2 Construction of an administrative building

The proposed new administrative building would principally be for the Administrative Sector, thus leaving the main building to the Scientific and Technical Sectors that need to be close to the machine and laboratories. The space so liberated by the Administrative Sector will serve a further purpose. This will be space for the much-needed laboratories referred to earlier (ChemLab, BioLab, MatLab).

The Administrative building will not only host the Administrative Sector but will also serve as a conference building, and on the ground floor there will be an auditorium with a seating capacity of 1200 persons, and a number of smaller rooms for meetings restricted in size or parallel sessions of larger meetings. The offices of all the administrative staff will be on the first floor. Once the administrative building has been completed, it will be possible to hold the Council meetings on the premises of SESAME.

4.3.3 Installation of an Uninterruptable Power Supply (UPS) and diesel generator for the security system and emergency lights

To avoid any instability or blackout in the electricity supply causing SESAME's security system, gates, fire alarm system and fence and street lights, all connected to the electricity network of the main building, being turned off, and the resulting dangerous situation this could give rise to, there is a need to install a UPS and diesel generator, and to connect the security systems and emergency lights to them.

4.3.4 Fire alarm system

A new fire alarm system needs to be designed and installed. This system should take all the drawbacks of the current system into consideration. Use may be made of the existing wiring system, or at least the tubes of the wiring system.

5 – Estimated Budget

5.1 SESAME's budgets

SESAME has two budgets. One is the operational budget for the daily operation of the Centre (i.e. staff costs, materials for maintenance and operation of the machine and beamlines, running of the Centre....). This budget is covered by the Members of SESAME, and the total yearly budget is distributed among them based on a system inspired from the principles of the UN scales. The yearly budget and its distribution among the Members are presented to the Council every year and require the unanimous approval by the Council.

The second is the capital budget for the construction of additional beamlines, major upgrades to the machine, and further development of SESAME's infrastructure. Although contributions to the capital budget are not obligatory, it is hoped that current (and future) Members will be in a position to provide some funding for this budget. Sources from where it is planned to seek such funding are given in point 5.5 below "Funding of SESAME capital budget".

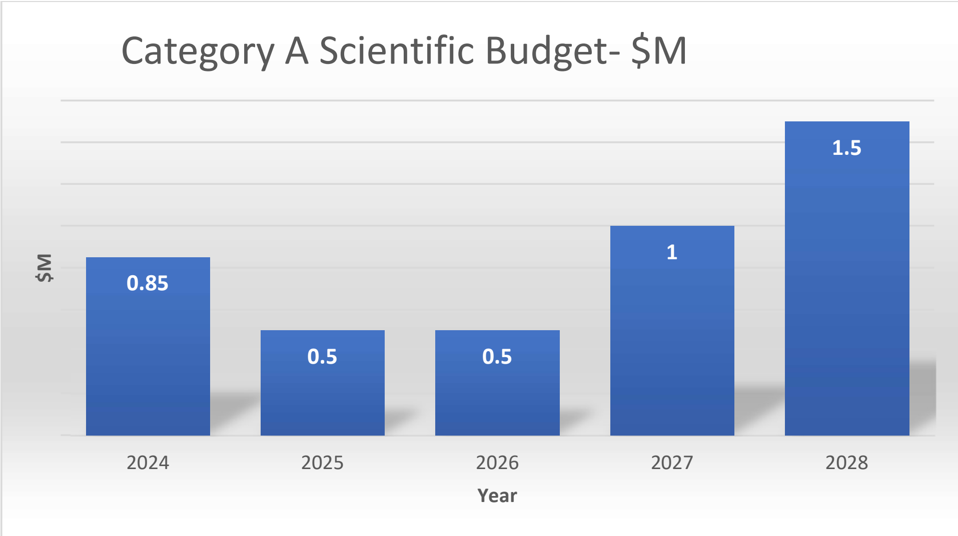
5.2 Capital budget

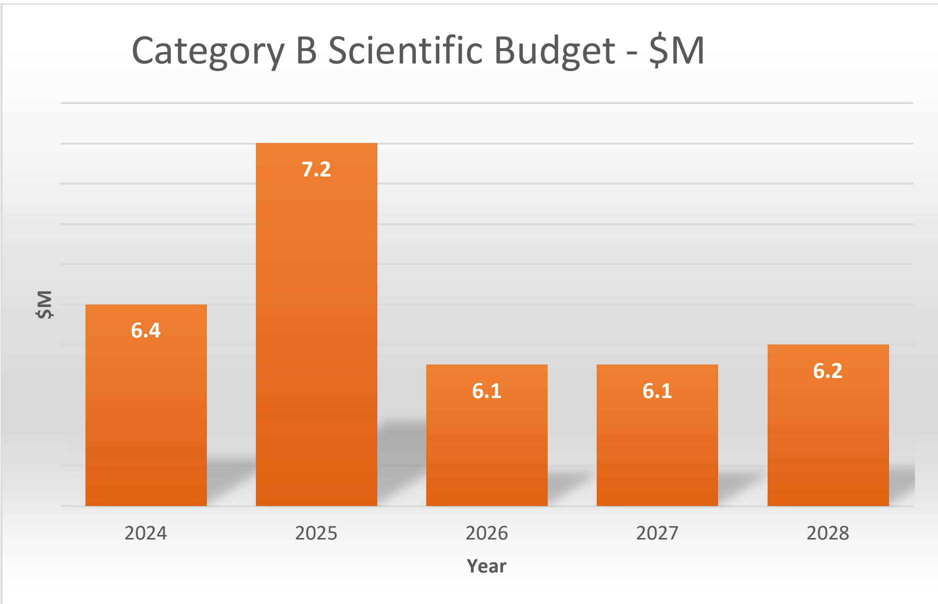
The scientific, machine and administrative capital budgets needed to fulfil the objectives set out in this Strategic Plan are listed in Tables 5.1, 5.2 and 5.3 below. In all three cases, the budget is divided into two categories. The first is Category A that groups all the actions that need to be taken in order to consolidate the existing beamlines and implement the gaps in the Scientific, Technical and Administrative Sectors. Implementation, during the period of the Strategic Plan, of all the actions that appear in this Category is mandatory for the sustainability of SESAME's activity. The second is Category B that groups all the actions that need to be taken to further develop SESAME. These actions will be subject to the availability of the required funding. They are highly desirable in order for SESAME to fulfil its role as a third-generation light source that is able to offer its users competitive facilities.

5.2.1 Scientific budget

Table 5.1: Capital scientific budget

Capital Scientific Budget						
Item	**Estimated Value ($M)**	**Cash Flow ($M)**				
		2024	**2025**	**2026**	**2027**	**2028**
Category A Budget (Must have)						
IR optics upgrade	0.200	0.200				
Focusing optics for XAFS (development)	0.350	0.350				
Sample preparation labs (ChemLab, BioLab, MatLab with small workshop)	3.800	0.300	0.500	0.500	1.000	1.500
Total Cat. A (must have) Budget	**4.350**	**0.850**	**0.500**	**0.500**	**1.000**	**1.500**
Category B Budget (Development)						
New detector for MS/XPD beamline	1.000		1.000			
Creation of a pool of sample environment instruments	1.000	0.400	0.200	0.100	0.100	0.200
Delivery of 5 new state-of-the-art beamlines	30.000	6.000	6.000	6.000	6.000	6.000
Total Cat. B Budget	**32.000**	**6.400**	**7.200**	**6.100**	**6.100**	**6.200**
Total 2024-2028 Scientific Budget	**36.350**	**7.250**	**7.700**	**6.600**	**7.100**	**7.700**

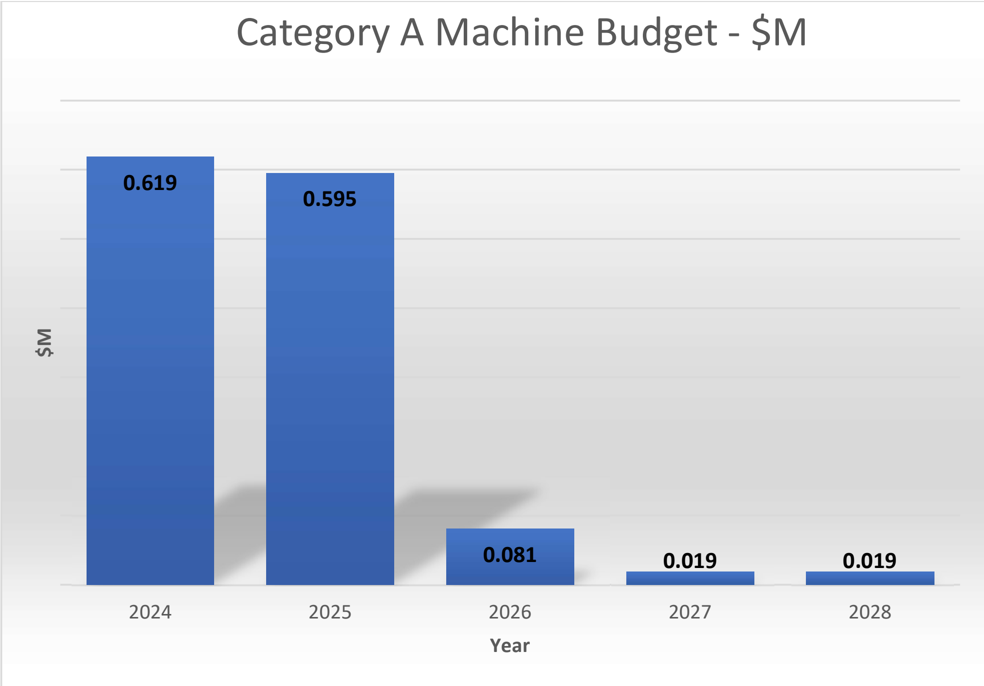

Category A Scientific Budget- $M
$M
0.85
0.5
0.5
1
1.5
2024
2025
2026
2027
2028
Year

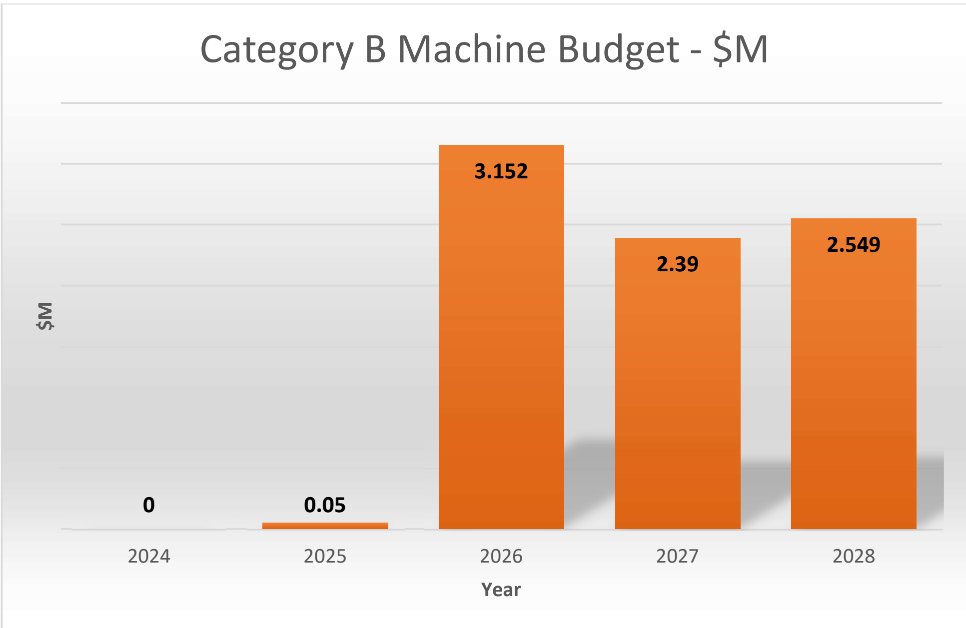

Category B Scientific Budget - $M
$M
6.4
7.2
6.1
6.1
6.2
2024
2025
2026
2027
2028
Year

5.2.2 Machine budget

Table 5.2: Capital machine budget

Capital Machine Budget						
Item	**Estimated Value (US$M)**	**Cash Flow (US $M)**				
		2024	**2025**	**2026**	**2027**	**2028**
Category A Budget (Must have)						
Injector refurbishment	0.045	0.045				
Machine spare parts	0.470	0.200	0.151	0.081	0.019	0.019
Digital delay line to complete the transverse multi-bunch feedback system	0.005	0.005				
Installation of a pinhole camera (X-ray diagnostics beamline) for precise beam size and instability measurements	0.014	0.014				
Electronics for X-ray BPMs in the beamlines	0.017		0.017			
Upgrading of the module unit of RF solid state amplifiers	0.004	0.004				
Upgrading of the cooling system	0.330	0.170	0.160			
Improvement of the performance of air compressed system	0.100		0.100			
Upgrading of the PLCs (phase I)	0.014	0.014				
Absorbers and beamlines' security boxes	0.014	0.007	0.007			
Fast orbit feedback (maximum cost)	0.320	0.160	0.160			
Total Cat. A (must have) Budget	**1.333**	**0.619**	**0.590**	**0.081**	**0.019**	**0.019**
Category B Budget (Development)						
Replacement of the microtron with a 100 MeV Linac	7.000			3.00 0	2.000	2.000
Addition of a 3rd chiller unit	0.140					0.140
Addition of a 3rd heat exchanger unit	0.010				0.010	
Upgrading of the air handling unit	0.017			0.017		
Procurement of a new RF directional coupler	0.003			0.003		
Procurement of lab equipment	0.140		0.050	0.040	0.030	0.020
Procurement of beam loss monitors	0.062			0.022	0.020	0.020
Procurement of a Time Correlated Single Photon Counting (TCSPC) system	0.040					0.040
Procurement of Libera processors for the remaining 16 BPMs	0.280				0.140	0.140
Installation of a longitudinal multi-bunch feedback system	0.090			0.030	0.030	0.030
Upgrading of the power supplies' controllers	0.065			0.025	0.020	0.020
Upgrading of the PLCs (phase II)	0.030			0.010	0.010	0.010
Upgrading of the PSS and EPS racks	0.014			0.005	0.005	0.004
Establishment of a magnetic measurement lab	0.250				0.125	0.125
Total Cat. B Budget	**8.141**		**0.050**	**3.152**	**2.390**	**2.549**
Total 2024-2028 Machine Budget	**9.474**	**0.619**	**0.645**	**3.233**	**2.409**	**2.568**

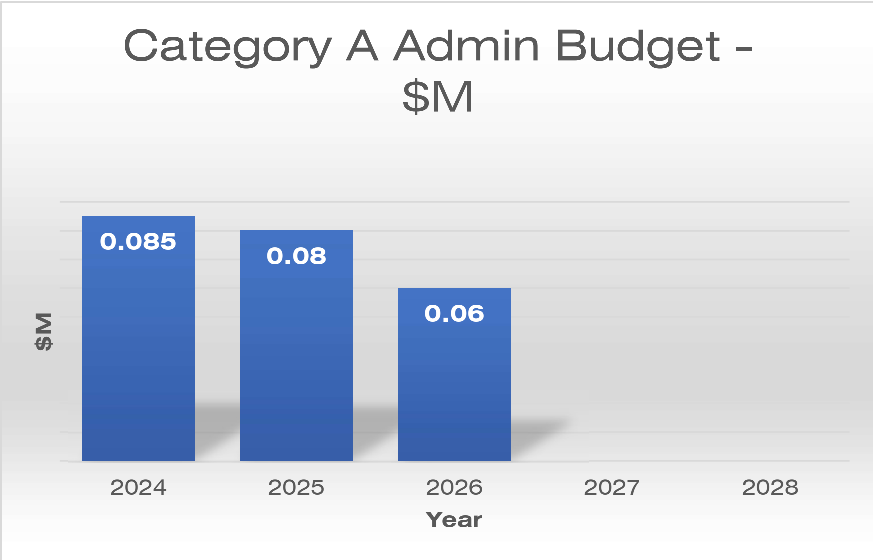

Category A Machine Budget - $M
$M
0.619
0.595
0.081
0.019
0.019
2024
2025
2026
2027
2028
Year

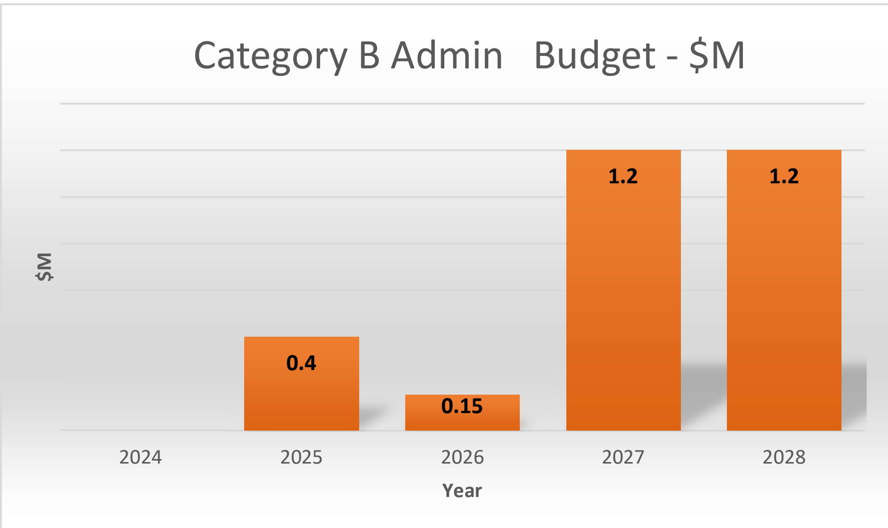

Category B Machine Budget - $M
$M
0
0.05
3.152
2.39
2.549
2024
2025
2026
2027
2028
Year

5.2.3 Administrative budget

Table 5.3: Capital administrative budget

Capital Administrative Budget						
Item	**Estimated Value ($M)**	**Cash Flow ($M)**				
		2024	**2025**	**2026**	**2027**	**2028**
Category A Budget (Must have)						
Renovation of the fire alarm system	0.050	0.050				
Earthing of the building, machine and beamlines	0.035	0.035				
Installation of a UPS and diesel generator for the security system and emergency lights	0.020		0.020			
Preparation of the infrastructure for the sample preparation labs	0.120		0.060	0.060		
Total Cat. A (must have) Budget	**0.225**	**0.085**	**0.080**	**0.060**		
Category B Budget (Development)						
Installation of a liquid nitrogen station	0.400		0.400			
Upgrading and development of the IT infrastructure	0.150			0.150		
Construction of an Administrative Building	2.400				1.200	1.200
Total Cat. B Budget	**2.950**	**0.000**	**0.400**	**0.150**	**1.200**	**1.200**
Total 2024-2028 Administrative Budget	**3.175**	**0.085**	**0.480**	**0.210**	**1.200**	**1.200**

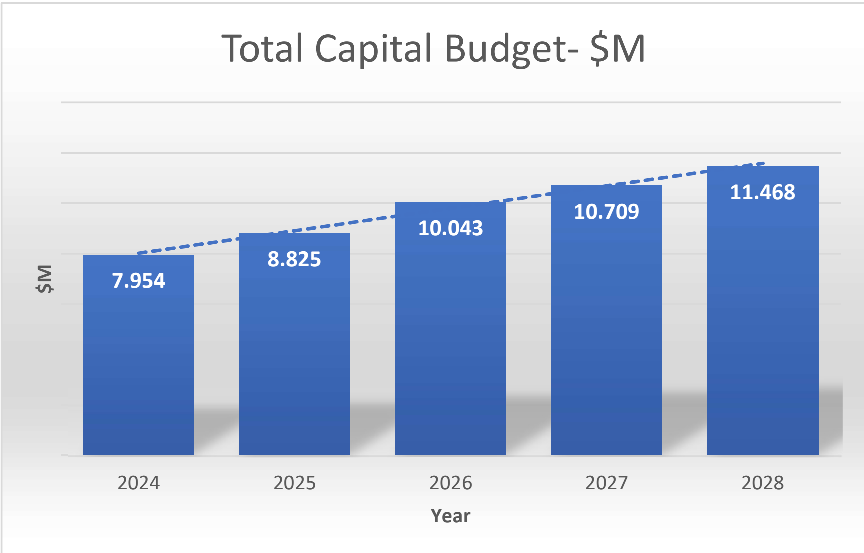

Category A Admin Budget - $M
$M
0.085
0.08
0.06
2024
2025
2026
2027
2028
Year


Category B Admin Budget - $M
$M
0.4
0.15
1.2
1.2
2024
2025
2026
2027
2028
Year

5.2.4 Total capital budget

Table 5.4: Total budget for all sectors

Total Capital Budget 2024 - 2028						
Item	**Estimated Value ($M)**	**Cash Flow ($M)**				
		2024	**2025**	**2026**	**2027**	**2028**
Total Scientific Budget	**36.350**	**7.250**	**7.700**	**6.600**	**7.100**	**7.700**
Total Machine Budget	**9.474**	**0.619**	**0.645**	**3.233**	**2.409**	**2.568**
Total Administrative Budget	**3.175**	**0.085**	**0.480**	**0.210**	**1.200**	**1.200**
Total Capital and Cash flow	**48.999**	**7.954**	**8.825**	**10.043**	**10.709**	**11.468**



5.3 Operational budget

For the purpose of this Plan, the operational budget is divided below into staff costs; other operational costs, i.e., consumables, services, electricity and other recurrent costs; parts and components for maintenance and small-scale upgrading of the machine and existing beamlines; and fixed assets, that is the acquisition of fixed assets such as computers, software and tools not directly connected to the machine and beamlines *per se*.

As will be seen from Table 5.10 below, the annual operational budget in 2024 will be US$5.289 million, and as SESAME expands its activity it will gradually increase on an annual basis to reach US$7.914 million in 2028.

5.3.1 Staff hiring plan

Table 5.5 shows the total number of staff posts required in each of the years 2024-2028. SESAME is short of staff in all sectors and hiring more staff is crucial for the sustainability of the Centre, and also to secure the staff needed for the new developments in the beamlines, the machine and the administrative infrastructure.

It is proposed to open 40 new positions for recruitment during the period 2024-2028 to be distributed as follows: 8 new positions in 2024, 21 in 2025, 4 in 2026, 2 in 2027 and 5 in 2028.

The large number of positions planned in 2025 is mainly to cover the needs for consolidating the present scientific infrastructure, improving the present capabilities of the SESAME machine and consolidating SESAME's infrastructure serving the machine and beamlines, as well as the developments to meet the strategic goals of this Plan.

Table 5.5: Staff hiring plan 2024-2028

D = Director P = Professional staff G = General Category T = Technical staff AD = Administrative staff	STAFF HIRING PLAN (2024 – 2028)																																					
	Created Posts up to 2023											Posts to be created 2024-2028																										Total
	Occupied Posts					Vacant posts					Total	Proposed new posts 2024					Proposed new posts 2025					Proposed new posts 2026					Proposed new posts 2027					Proposed new posts 2028					Total to be create	
	D1	P	G AD	G T	Total	D1	P	G AD	G T	Total		D1	P	G AD	G T	Total	D1	P	G AD	G T	Total	D1	P	G AD	G T	Total	D1	P	G AD	G T	Total	D1	P	G AD	G T	Total		
Scientific Sector																																						
Scientific Director	1				1																																	1
Beamlines		8		1	9		2			2			1		1	2		5		2	7		1			1		1			1		3			3	14	25
Data Collection and Analysis		2			2													1			1		1			1											2	4
Detectors and Electronics		1		2	3																																	3
Optics and Metrology																																						
Scientific Computing & Systems Communications		3			3													1			1																1	4
Support Laboratories													1		1	2		2		2	4							1			1				2	2	9	9
Users Officer		1			1															1	1																1	2
Total Scientific Sector	**1**	**15**		**3**	**19**		**2**			**2**	**21**		**2**		**2**	**4**		**9**		**5**	**14**		**2**			**2**		**2**			**2**		**3**		**2**	**5**	**27**	48
Technical Sector																																						
Technical Director	1				1																																	1
Accelerator Physics		1			1																																	1
Controls		5		1	6		1			1								1			1																1	8
Diagnostics		2		1	3				1	1																												4
Electrical Engineering and Power Supplies		3		2	5										1	1																					1	6
[illegible]																				1	1		1			1											2	2
Mechanical Engineering		2		1	3										1	1				1	1																2	5
Operation		1			1		2		2	4																												5
Radio Frequency		2		1	3		1			1																												4
Vacuum		4		4	8										1	1				1	1																2	10
Total Technical Sector	1	20		10	**31**		4		3	**7**	38				3	**3**		1		3	**4**		1			**1**											**8**	46
Administrative Sector																																						
Administrative Director	1				1																																	1
Administrative Services			1	4	5																																	5
Finance & Accounting		1			1		1			1								1			1																1	3
Human Resources		1	1		2																		1			1											1	3
IT Support		1	1		2			1		1			1			1																					1	4
Procurement		2	3		5													1			1																1	6
Security								1		1																												1
Site and Building		1	1		2																																	2
Total Administrative Sector	1	6	7	4	**18**		1	2		**3**	21		1			**1**		2			**2**		1			**1**											**4**	25
Director's Support Offices																																						
Communication & Public Relations							1			1																												1
External Relation & International Projects		1			1													1			1																1	2
Internal Auditing							1			1																												1
Quality Assurance							1			1																												1
Safety		2			2																																	2
Total Director's Support Offices		3			**3**		3			**3**	6							1			**1**																**1**	7
Total SESAME	3	44	7	17	71		10	2	3	15	86		3		5	8		13		8	21		4			4		2			2		3		2	5	40	126

5.3.2 Staff costs

Table 5.6: Staff costs

Staff Costs (including Directors) - $M				
2024	**2025**	**2026**	**2027**	**2028**
3.606	**4.451**	**4.830**	**5.198**	**5.648**

5.3.3 Other operational costs

Table 5.7: Other operational costs

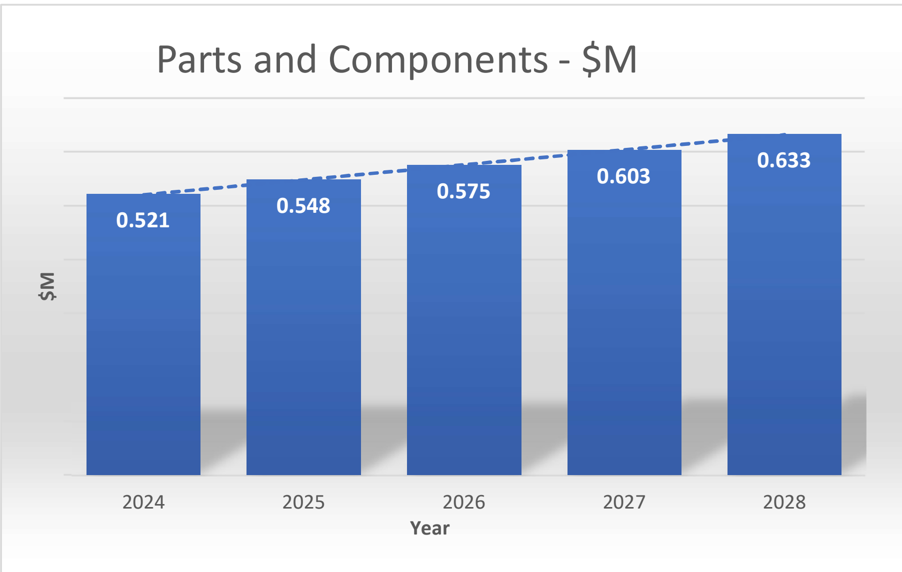
Other Operational Costs - $M					
Item	**2024**	**2025**	**2026**	**2027**	**2028**
Consumables	0.190	0.283	0.292	0.300	0.310
Services*	0.348	0.348	0.364	0.380	0.391
Electricity	0.200	0.206	0.212	0.219	0.225
Other Recurrent Costs	0.192	0.270	0.278	0.286	0.295
Total	**0.930**	**1.107**	**1.146**	**1.185**	**1.221**

* Included in this sum is the cost of the operation and maintenance of the solar power plant which is to be borne by SESAME from March 2024 onwards.

5.3.4 Parts and components

Table 5.8: Parts and components of the machine and beamlines

Operational Budget - Parts and Components						
Item	**Estimated Value (US$M)**	**Cash Flow (US$M)**				
		2024	**2025**	**2026**	**2027**	**2028**
Scientific						
New optics for IR	0.100	0.100				
Focusing optics for XAFS	0.250	0.250				
Spare parts and maintenance of the beamlines	1.584		0.368	0.386	0.405	0.425
Machine						
Spare parts for the machine	0.901	0.126	0.180	0.189	0.198	0.208
Refurbishment of the injector system	0.045	0.045				
Total Parts & Components Operational Budget	**2.880**	**0.521**	**0.548**	**0.575**	**0.603**	**0.633**



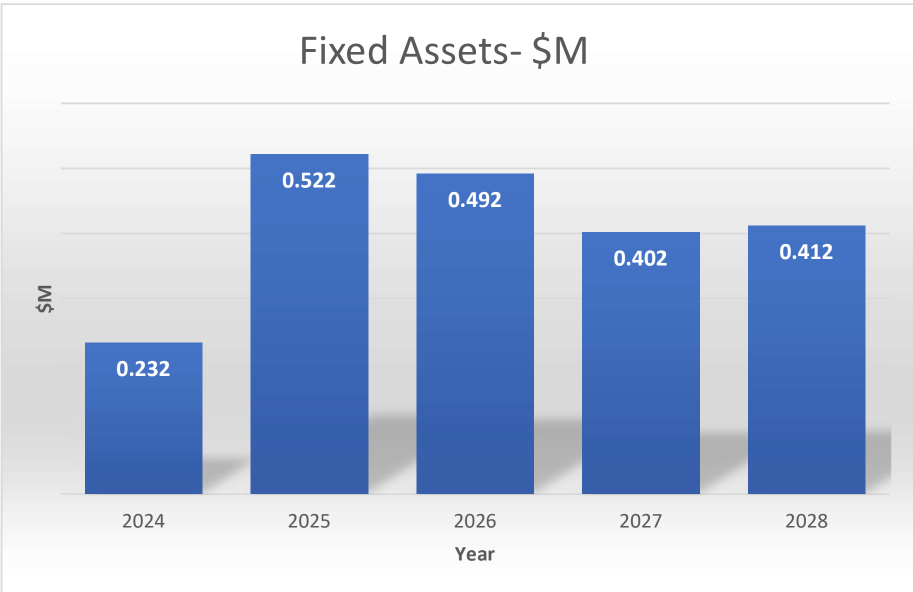
5.3.5 Fixed assets

Computers, software and networking, furniture and equipment for the building, etc.

Table 5.9: Fixed assets 2024-2028

Operational Budget – Fixed Assets						
Item	**Estimated Value (US$M)**	**Cash Flow (US$M)**				
		2024	**2025**	**2026**	**2027**	**2028**
Fixed Assets	2.060	0.232	0.522*	0.492	0.402	0.412

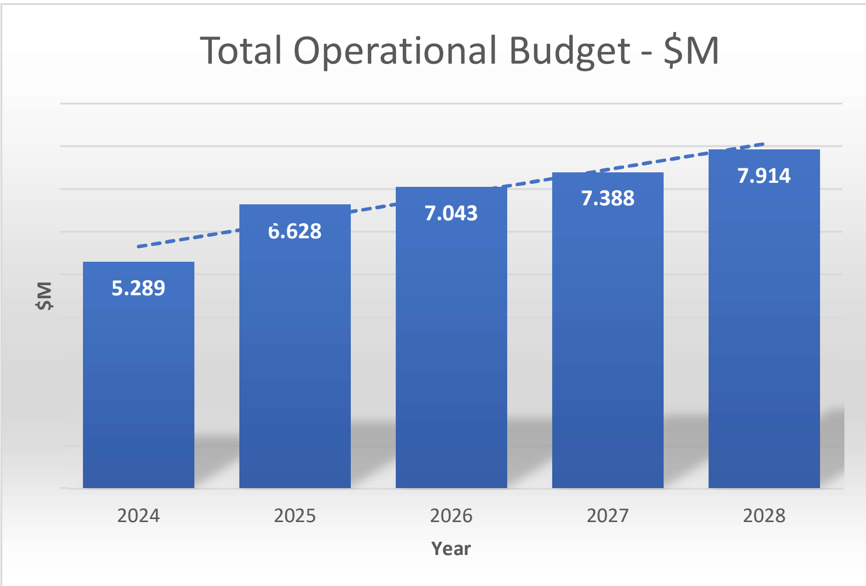
* Starting from 2025 it is planned to gradually replace the computers, servers and centralized storage hardware and install an archiving system for the long-term storage of experimental data as per SESAME's experimental data management policy.



5.3.6 Total operational budget

Table 5.10: Total operational budget 2024-2028

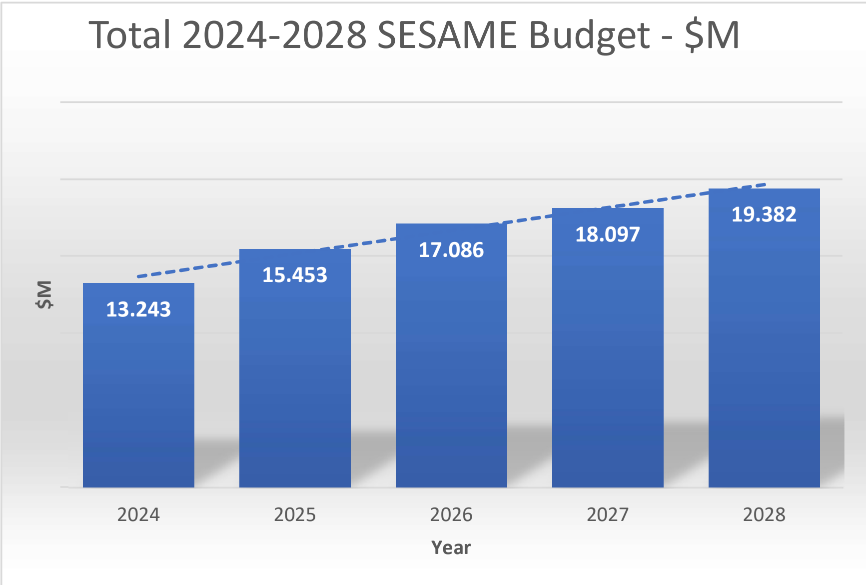
Total Operational Budget - US$M					
Item	**2024**	**2025**	**2026**	**2027**	**2028**
Staff Costs	3.606	4.451	4.83	5.198	5.648
Other Operational Costs	0.930	1.107	1.146	1.185	1.221
Parts & Components	0.521	0.548	0.575	0.603	0.633
Fixed Assets	0.232	0.522	0.492	0.402	0.412
Total	**5.289**	**6.628**	**7.043**	**7.388**	**7.914**



5.4 Total 2024-2028 budget

Table 5.11: Total 2024-2028 SESAME budget

Total 2024-2028 SESAME Budget - $M					
Item	**2024**	**2025**	**2026**	**2027**	**2028**
Operational budget	5.289	6.628	7.043	7.388	7.914
Capital budget (Cat A + B)	7.954	8.825	10.043	10.709	11.468
Total	**13.243**	**15.453**	**17.086**	**18.097**	**19.382**



5.5 Funding of SESAME's capital budget

One of the main hurdles that SESAME has faced ever since its inception in 2004 has been the capital funding. While the operational funds have always been provided by the Members' annual contribution, capital funding has always been difficult to obtain despite the generous contributions from national and international organizations and governments. The table below shows the funding and in-kind contributions SESAME has received up to, and including, July 2023, and the effective value of this for SESAME. The table does not include funding received for capacity building and outreach.

Table 5-12: Total cash, grants and in-kind contributions received by SESAME up to, and including, July 2023

	Funds received by SESAME as at 31 July 2023			
Description	**Amount/ value US$M**	**Effective value to SESAME US$M**		**Origin**
Immovable property (land, building, electrical power line, etc.)	12.770	12.770	100%	Jordan
Donation in 2002 of BESSY I components	~10.000	4.000	40%	Germany
Equipment for the SESAME machine	1.850	0.560	30%	USA, Italy and UNESCO
Beamlines and beamline components donated to SESAME	23.300	11.650	50%	UK, France, Switzerland and USA
Cash donations for construction of SESAME machine	3.380	3.380	100%	Royal Court of Jordan (0.28 from MoE)
	~ 18.400	18.400	100%	EU (machine + Solar Power Plant)
	15.000	15.000	100%	Israel, Jordan and Turkey (part of voluntary contribution agreement)
Cash donation from Italy	~ 3.960	3.960	100%	Italy (includes guest house)
Conference room	0.030	0.030	100%	Switzerland
Guest house cafeteria	~0.033	0.033	100%	Sharing knowledge Foundation
Equipment, devices and spare parts	~ 0.443	0.443	100%	IAEA TC projects
Beamline equipment	~ 0.072	0.072	100%	UK
HESEB beamline	3.900	3.900	100%	Germany
BEATS beamline	6.700	6.700	100%	EU
Two Libra processors+Libra digital front end	0.040	0.040	100%	Australia (ALS)
GPS receiver, front-end computers and electronic boards	0.005	0.005	100%	CERN
Machinery for workshop	0.025	0.025	100%	Germany (DESY)
Feedthroughs, moving stage and isolation couplings	0.005	0.005	100%	UK (Oxford University)
Solid State Magnetron Modulator and electronic components	0.216	0.216	100%	Italy (INFN)
Solid State Magnetron Modulator	0.152	0.152	100%	Switzerland (PSI)
Libera and amplifiers	0.385	0.385	100%	Canada (CLS)
Longitudinal kicker	0.020	0.020	100%	Brazil (CNPEM)
Manpower + operational	39.751	39.751	100%	SESAME Members
Total		**121.497**		

5.5.1 Future sources of capital funding

Having capital funding is fundamental for the development of SESAME and for enhancing its capabilities and performance. The following 6 points suggest a few possible ways of generating such resources for SESAME.

5.5.1.1 Payments of delayed contributions

There will be measures to be applied to those Members having long-standing debts which it is hoped will result in recovery of these debts. Such payments may, in part or in full, be transferred to the capital budget.

5.5.1.2 Voluntary donations by SESAME Members

Due to the absence of the required funding, in 2011, the real construction of the SESAME machine had not yet started, and, after having been greatly upgraded, only the microtron and booster donated by Germany had been installed.

In a meeting held in Jordan in March 2012, which was attended by representatives of four SESAME Members and a representative of UNESCO, and chaired by the President of the SESAME Council, the four Members (Iran, Israel, Jordan and Türkiye) committed themselves to providing US$5 million each to be paid over five years. This commitment was instrumental in prompting the European Commission to provide €5 million for construction of SESAME's 2.5 GeV new storage ring.

This voluntary donation was received from three of these Members, but to date one Member (Iran) has been unable to transfer its funds due to international or bilateral sanctions.

One could perceive a similar scenario for the development of SESAME over the next five years. A special meeting of the Members could be held at SESAME to review progress and the need for capital investment to keep the centre advancing, as well as to show at first-hand how SESAME can serve their national science. SESAME will have brochures and videos designed and produced for the meeting with the help of a professional marketing agency or expert, and it will give a copy of this material to the Members' representatives taking part in the meeting so that they may use it to convince their national policy- and decision-makers of the importance of making SESAME, which is their organization, a better place for science.

5.5.1.3 Commercial sale of SESAME beam time

Industry may greatly benefit from SESAME's beamlines and other facilities, as well as the skills of its staff. This is notably the case of the materials, medical, health, geological, and petrochemical industries. SESAME could design different business models to serve the needs of the industry while staying within its principles and rules. Industry in some cases requires confidentiality of the experimental data and results. Some business models also have this requirement. All business plans would need to be approved by the SESAME Council.

5.5.1.4 International funding projects

TC (Technical Cooperation) and CRP (Coordinating Research Projects) projects of the IAEA could be an excellent source of funding. Funding through EU projects has been a very good source of funding and through this has served to reinforce the European synchrotron radiation facilities' already-existing cooperation with SESAME. The possibility of obtaining further EU support could be explored.

5.5.1.5 New and Associate Members

Associate Membership contributions should all be used for capital investment. This should also be the case of a new Member's one-time joining fee.

5.5.1.6 Associate synchrotron laboratories

Associate laboratories may help by providing parts and components for SESAME that are in good condition. This may be in the form of a donation or a loan for a set duration.

6 – Communication and Outreach

6.1 Objectives of communication and outreach

SESAME plans to develop a communications and outreach strategy to reach out to the scientific community in its broadest sense, policy- and decision-makers, and the public at large. It will set up for this purpose a communications and outreach team in the Director's Communication/Public Relations support office. This team will be responsible for highlighting SESAME's capabilities and giving greater visibility to high-impact research carried out by users and the staff to a diverse set of audiences, including current and potential users, research centres, universities, representatives of SESAME's Members, other synchrotron facilities, and the public at large.

It will do so *inter alia* through written material such as a newsletter, *ad hoc* leaflets, press releases, and articles and highlights on SESAME's web site, as well as tours of the laboratory and verbal presentations about the Facility.

Among the channels of communication that will be used to implement this strategy will be the social media, SESAME's web site, an electronic mailing list, and in-person and online meetings.

6.1.1 Consolidation activities

To ensure returns of the investments made in SESAME and strengthen the Facility's position as an international research infrastructure and centre of excellence in the Middle East and beyond, communication and outreach will focus on the following:

Community development and impact generation for SESAME by encouraging existing and new scientific user communities in the Middle East and neighbouring countries to utilize SESAME's facilities. Researchers, both junior and senior, will be mobilized to take part in activities in order to gain practical knowledge.

Visibility of SESAME among current and prospective stakeholders of the Facility. Programmes will include face-to-face forums and workshops with the participation of high-level representatives of stakeholders. Actions will draw from existing methodologies elaborated to increase membership of SESAME.

Capacity building and the development of skills of African scholars in anticipation of the setting up of a light source in Africa. Programmes will include workshops, and student and researcher mobility projects.

6.1.2 Existing synergies

Efforts will build naturally upon existing international cooperations, and there will be new long-term bridges to researchers in the Middle East and Africa.

The "OPEN SESAME" and "BEATS" projects, which set the basis for effective European collaboration with SESAME, could be used as leverage to create a further project, this time to utilize SESAME as a training centre in its own right in partnership with the European LEAPS facilities and the Brazilian 4th generation synchrotron light facility Sirius. SESAME has, in fact, already taken steps in this direction since on 6 July 2022 it organized an online workshop with African researchers. It did so in partnership with the AfLS and the BEATS and HESEB consortia. Among the speakers was the Director of the Office of Science of the US Department of Energy.

Moreover, cooperation with Africa may eventually result in the realization of an African beamline at SESAME, thereby providing an important physical training base at SESAME for African and other potential users. It is expected that high-profile actors beyond the synchrotron world already active with researcher communities and university networks in the Middle East and Africa, such as the IAEA, IUCr (International Union of Crystallography) and IUPAP (International Union of Pure and Applied Physics), would associate themselves with these activities and activate their networks in support of the project goals. This will leverage existing networks and will result in a more rapid and strong impact on building the capacity of African users.

6.2 Elements of SESAME's communication strategy

SESAME's communication strategy will consist of the following elements working interdependently:

a) Training for junior scientists in the use of synchrotron radiation for their research and in this way not only improving the capacity of these scientists, but also making them aware of the opportunities SESAME offers for their work. This may be achieved through:
   i. Introductory workshops for potential new Facility users and training activities for the future generation of scientists, or
   ii. A monthly (or quarterly) webinar to be advertised on the distribution channels.

b) Posting on YouTube of a virtual tour of SESAME developed by a professional company. The link to the tour will be posted on the web site of SESAME and circulated to relevant organizations and institutions.

c) Publication of a SESAME monthly e-newsletter and quarterly e-news magazine and *ad hoc* leaflets tailor-made for a specific purpose or event. Examples of the contents of the magazine would be:
   i. News relating to SESAME's science, beamlines, accelerators, infrastructure, activities, and staff; and
   ii. Excerpts from the magazines or newsletters of other light sources, and possibly highlights of global scientific achievements in general.

Initially, the magazine will only consist of one page or a few pages and with time it may be expanded to a greater number of pages.

d) Issuing of an annual report on all of SESAME's activities. This report will be produced in both digital and printed form. Only a limited number of printed copies will be produced. The digital version will be available online for any interested reader, and a link to it will be e-mailed to those on SESAME's mailing list.

e) Issuing of web news articles and press releases covering fresh news as it happens. These articles and press releases will immediately be posted on SESAME's website, and the press releases will also be circulated to the press. They may also be published as news feed on social media.

f) Participation of SESAME's staff in the activities, programmes, conferences and workshops of other synchrotron facilities, groups and organizations.

g) Networking and collaboration with national and multinational companies to sensitize them to the research opportunities SESAME offers for their work. Networking with industry is important for the following reasons:

    i. Researchers from industry may bring new ideas and research perspectives to SESAME.

    ii. Researchers from industry might be able to share with other SESAME researchers, their available facilities and data to enhance the outcome of the research they are part of.

    iii. Researchers from industry typically have specific problems that need very advanced scientific tools, such as synchrotron radiation, to find solutions.

6.3 Elements of SESAME's outreach strategy

SESAME's outreach strategy will target the general public, school and college students, K-12 educators, politicians, and legislative bodies. It will consist of the following elements:

a) Tour of SESAME for both scientists based in Jordan and scientists visiting Jordan who are interested in using synchrotron facilities. During these tours, which may be of a day's duration or more, there will be a demonstration of the Facility's capabilities, and information will be given on the opportunities offered by synchrotron radiation, and SESAME in particular.

b) Tour of SESAME for high-school and college students in Jordan and the SESAME region, and a presentation about the Facility, its achievements and the research opportunities it offers users. Such tours will be organized on the request of the schools and colleges. SESAME may, on its own initiative, invite schools and colleges for a tour of SESAME.

c) Tour of SESAME for science teachers in schools in Jordan and the SESAME region, and a presentation about the Facility. Teachers are to apply for such a tour. Logistics in Jordan may be arranged for those teachers in schools away from Jordan whose application has been accepted. This includes a one-night stay at SESAME's guest house free of charge.

d) Tour of SESAME for politicians, policy- and decision-makers, Ambassadors, Embassy staff and other high-profile persons based in Jordan or elsewhere, and a presentation about the Facility, its achievements and the opportunities it offers for national priority projects. Such tours are organized on the request of any of these entities. SESAME may, on its own initiative, invite these high-profile individuals for a tour of SESAME.

e) An annual SESAME Open Day for the general public. Relevant institutions may be invited to take part in the Open Day to showcase their interaction and collaboration with SESAME.

6.4 Channels of communication for implementation of SESAME's communication and outreach strategy

Among the channels of communication that SESAME will use to implement its communication and outreach strategy are the following:

a) SESAME's web site and mailing list

b) Lighsources.org's website

c) Social media: Facebook, Twitter, LinkedIn, Instagram, Flicker, TikTok, and YouTube.

d) WhatsApp groups.

e) Meeting; Forums, Conferences, and Workshops.