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D4.7

Business plan assessment and revision

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Disclaimer:

Versioning and Contribution History

Version	Date	Modified by	Modification reason
v.01	16/07/2021	Valerio Lunardelli	First Version
v.02	21/07/2021	Arrigo Calzolari	Revision
v.03	28/07/2021	Mara Di Berardo, Luisa Neri	Final revision

Contents

[1] Acronyms are marked in purple in the text and defined at the end of the document.

1. Executive Summary

Solution of complex problems (e.g. production of new technology) requires the combination of advanced knowledge and state-of-the-art technologies, belonging to interdisciplinary areas. In this regard, the INTERSECT project aims at leveraging European leadership in materials' modelling software and infrastructure, providing an industry-ready novel multi-scale multi-physics simulation platform, able to connect materials simulations to modelling of the device operations. INTERSECT's main result will be the release of the Interoperable Material-To-Device Simulation Box (IM2D) that is conceived as an interoperable, robust and friendly software solution for easier exploration of the materials workspace from an electronic device-oriented industrial perspective. Beside the overall IM2D infrastructure, a set of key exploitable results (Table 1) has been selected and ranked, as a result of the innovation management analysis (see deliverable D4.8 "Innovation management assessment and revision").

#	WP	Key exploitable results
1	All	IM2D platform
2	2	Ginestra-AiiDA interface
3	2	AiiDA-QE interface
4	2	AiiDA-SIESTA interface
5	2	Properties Workflows
6	3	Analysis of complex systems
7	2	Semantic wrappers

Table 1. List of key exploitable results resulting from the Assessment phase of the innovation management analysis.

The scope of this report is to provide an updated Business model for the project results. For each of the key exploitable results of Table 1, we elaborated a dedicated business model canvas. Since IM2D is the main project outcome, it will cover the largest part of this plan. An initial business strategy for the exploitation of IM2D was anticipated in the "First Business plan" (D4.3) that is now elaborated on the basis of the maturated experience, also in contact with industrial stakeholders. The business models for the remaining six exploitable results are, instead, completely new, as these key results emerged from an innovation management analysis performed after the release of the first business plan.
In accordance with the Description of the Action (DoA) and the Consortium Agreement expectation among participant partners, "the project goal is the realization of a 'pre-competitive' software solution". Therefore, in this business plan assessment we will analyze the market size, the segmentation and the needs of the reference sector market - the

Electronic Design Automation (EDA) market - and of the main end-user markets (semiconductor and neuromorphic market), without entering into specific commercialization or marketing strategies, which go beyond the aim of this project.

The rest of the document is organized as follows:

- Section 2 – Vision & Mission
- Section 3 – INTERSECT product and solution business models
- Section 4 – Market research: segmentation, trends & opportunities and INTERSECT positioning
- Section 5 – SWOT analysis
- Section 6 – Exploitation strategy
- Section 7 – Marketing plan: revenue, distribution, source license type and communication plan
- Section 8 – Conclusions

1.1 About this document

In this deliverable we will describe the business models with the business model canvas for each key exploitable result starting from the Exploitation phase lines described in D4.8. This document updates and revises the initial business strategy reported in the "First Business plan" (D4.3).

2. Vision & Mission

2.1 Vision

Pursuing and accelerating the design of defective complex materials and devices for application in emerging technologies.

2.2 Mission

INTERSECT mission is to exploit the synergic interplay among material and device simulation tools to reduce the gap between ideal and "real-life" materials in the modelling of disruptive devices, for a direct and easy exploitation by industrial users. The INTERSECT declared intent is to support and develop the competitiveness of semiconductor companies, including SMEs or startups (especially in Europe) that may suffer the competition with the tech-giants from US or Asia.

3. Product and Solutions business models

In this chapter we will describe the key exploitable results (Table 1) and the proposed business models, along the lines elaborated in the exploitation step of the revised innovation management plan (D4.5 “Innovation Management Plan”, D4.8 “Innovation management assessment and revision”).

3.1 IM2D

Description

IM2D is an integrated, standardized, interoperable software platform conceived for the direct and easy exploitation by industrial users to accelerate the development of emerging electronic devices such as FeFET, memristors (e.g. PCM, RRAM), and selectors. IM2D is based on a multi-physics (Density-Functional Theory - DFT, MonteCarlo, electrodynamics) and multiscale approach with focus on novel, complex, “real life” materials in the specific device configuration. IM2D conjugates the advantages of material and device-driven software, connecting the properties of materials at the atomistic level to the electrical behavior of devices.

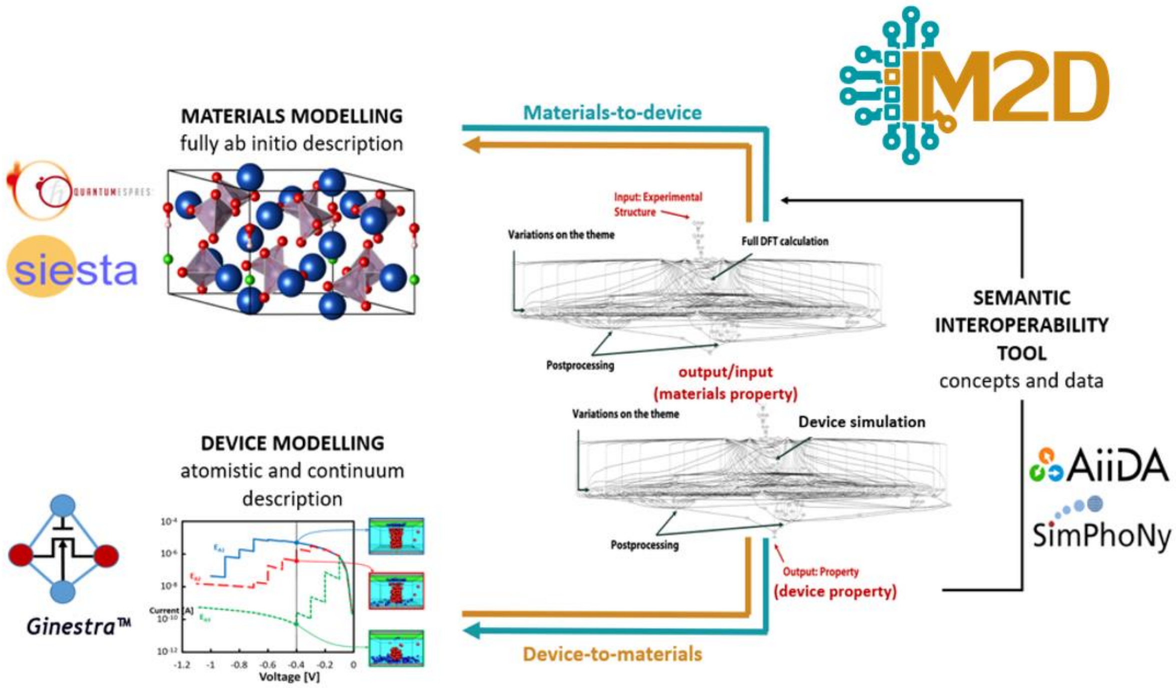


Figure 1. IM2D framework description.

As described in detail in D2.4, IM2D supports two main research operation modes:

- **Material-to-Device** (M2D): optimization of device-design capabilities by understanding and predicting the device performance starting from the material properties and fabrication process effects;

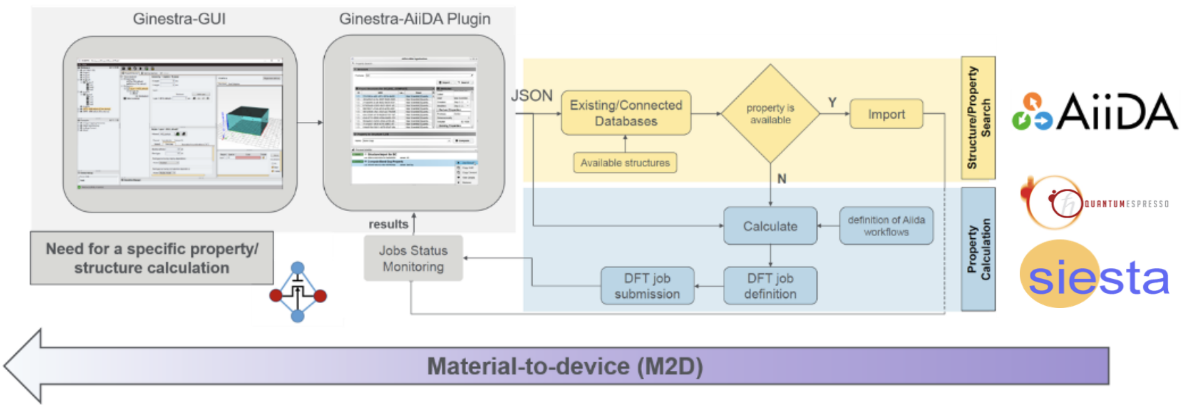


Figure 2. M2D workflow.

- **Device-to-Material** (D2M): optimization of material-design capabilities by exploring new materials and new compounds, starting from the desired electrical performances of the device.

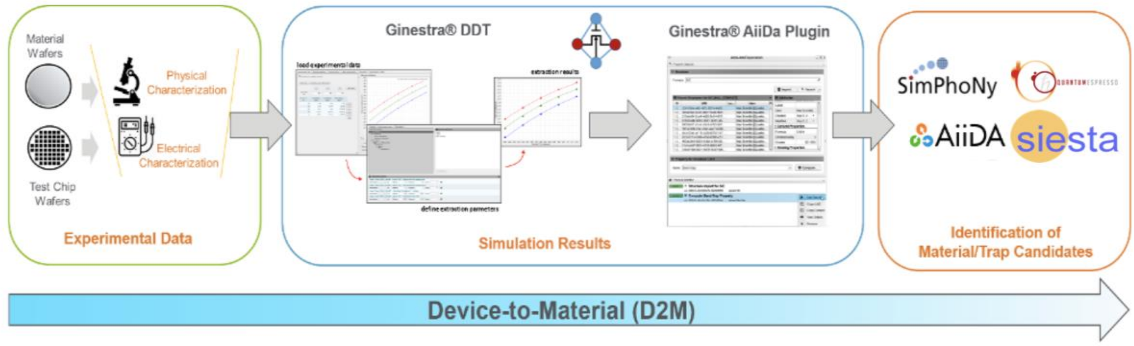


Figure 3. D2M workflow.

Business model

IM2D has a hybrid business model, as it comprises open source and commercial business models. DFT engines (Quantum ESPRESSO and SIESTA) and SimPhoNy are open source codes, the AiiDA infrastructure is distributed with a MIT licence, while Ginestra^{TM} is an Applied Materials proprietary software that is commercialized with a time-based license: in order to to use some IM2D functionalities that require Ginestra^{TM}, an IM2D user should purchase a time-based license. The rest of IM2D is available for free.

Business model canvas

<table>
<tr>
<td rowspan="2">KEY PARTNERS
INTERSECT Consortium
EMMC Network
European Semiconductor Industry Association (ESIA) members
Computational centers (e.g., CINECA)
EU semiconductor industries (IBM, STM, etc.)
EMMC Marketplace Members
Code developer teams</td>
<td>KEY ACTIVITIES

Development, maintenance and update of IM2D platform</td>
<td rowspan="2">VALUE PROPOSITIONS
Materials properties on demand from quantum mechanical DFT calculations
Device modelling: physics-based description of charge/ion transport and charge trapping
Virtual lab for device characterization
Reliability and variability analysis
Optimization and design of devices
Different pre-selected user's knowledge levels
Automated workflows for multistep simulation and data curation
Access to materials databases
Easy friendly graphical interface and analysis tools
Possibility to protect data on private firewall</td>
<td>Stakeholder RELATIONSHIP

Git-HUB for co-creation of the solution

Creation/Contribution to scientific communities

IT/trainings for supporting the combination of the software usage</td>
<td rowspan="2">Stakeholder target SEGMENT
EDA Software and more specifically the Technology-Computer-Aided Design (TCAD)
EU Semiconductor industries
Scientific & Professional Communities</td>
</tr>
<tr>
<td>KEY RESOURCES

Software connected & integrated in IM2D
SimPhoNy
AiiDA
QE
SIESTA
Ginestra™</td>
<td>CHANNELS
Project/partners GitHub
Marketplace
INTERSECT and partners' websites
INTERSECT newsletter
INTERSECT and partners' social media activities
Targeted mailing/announcements to key partners/selected segments
Conferences/R2B/trade shows events</td>
</tr>
<tr>
<td colspan="2">COST STRUCTURE

Personnel

Travels

Cloud/IT infrastructures

Dissemination costs</td>
<td colspan="3">REVENUE STREAM (prospects)

Mixed free and proprietary software

Ginestra™ → licensing fee

Consulting fees</td>
</tr>
</table>

Table 2. Business model canvas for IM2D.

Market	Source code license	Distribution strategy
Sector ● EDA Market **Segment** ● Computer-Aided Engineering (CAE) ● Computer-Aided Design (CAD), subsegment of Integrated Circuit (IC) physical design **End User market** ● Semiconductor ● Neuromorphic computing/Artificial Intelligence (AI)	Mixed proprietary and open source	Hybrid on premises and cloud based

Table 3. Market, source code license and distribution strategy for the IM2D.

3.2 Ginestra-AiiDA interface

Description

The INTERSECT Ginestra-AiiDA interface is conceived to exchange European Material Modelling Ontology (EMMO) compliant data from/to the AiiDA database in both the M2D and D2M workflows. Its realization has represented one main step toward the implementation of the syntactic interoperability and the realization of the simulation hub of IM2D, as it allows for the interconnection via AiiDA of the device (Ginestra^{TM}) and of the materials (SIESTA, QE) codes. For M2D workflow, it is possible to retrieve/import a crystalline structure, retrieve a physical property, or submit/monitor the property computation. In case of D2M the interface queries the AiiDA database via the REST-API, looking for the materials that match the outputs of the first block. Query may be refined according to specific filters: candidate materials list, variability range for the parameter, concatenation of multiple conditions (e.g., the material should satisfy both the band-gap and the dielectric constant values).

Business model

Being the Ginestra-AiiDA plugin a genuine outcome of the INTERSECT project, it will be released as Open Source Software (OSS): General Public License (GPL) or Lesser GPL (LPGL). Leveraging the Ginestra-AiiDA interoperability, this open source product can drive Ginestra™ revenues and/or material characterization and/or device modeling consulting services.

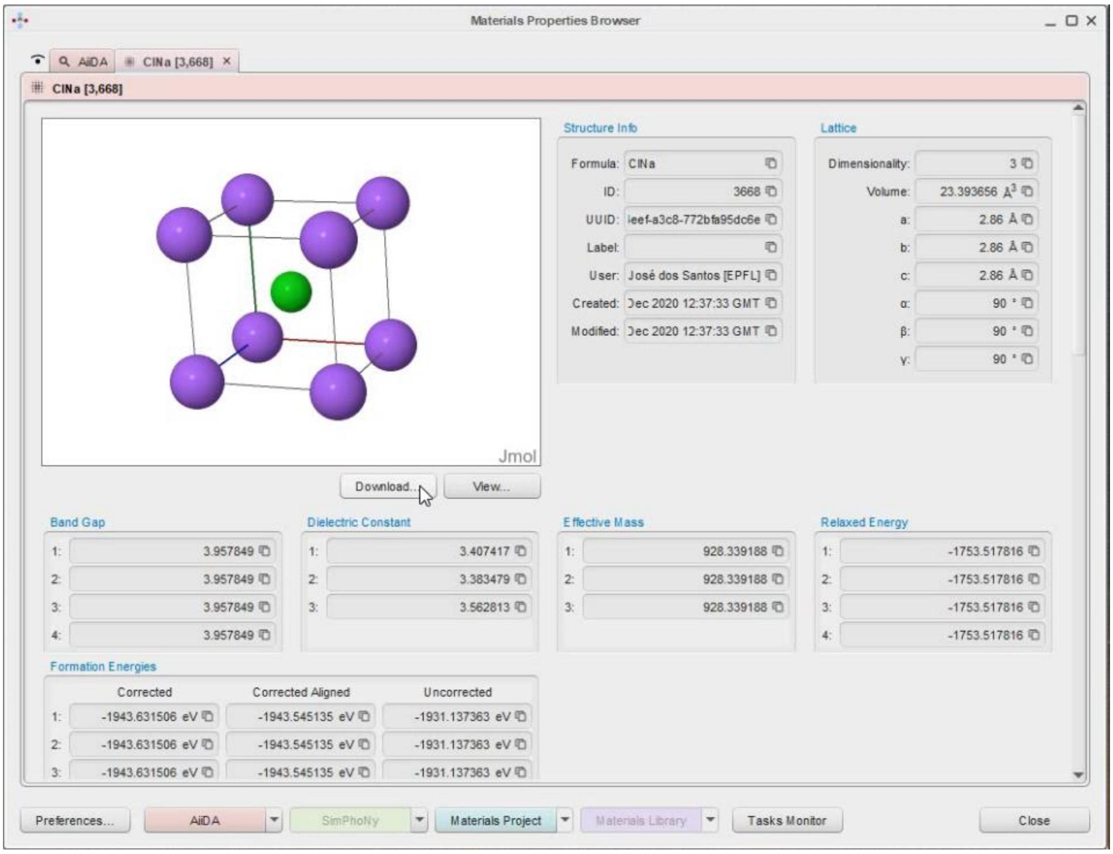


Figure 4. AiiDA-Ginestra Interface.

Business model canvas

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITIONS	Stakeholder RELATIONSHIP	Stakeholder target SEGMENT
• AMAT • EPFL	Development, maintenance and update of Ginestra-AiiDA interface	• Retrieve/import a crystalline structure, retrieve a physical property, or submit/monitor the property computation • Queries the AiiDA database via the REST-API looking for the materials that	• Ginestra™ simulation platform • AiiDA GitHub • Training for supporting the combination of the software usage	• EDA Software and more specifically the TCAD • EU Semiconductor industries • Scientific & Professional Communities

	KEY RESOURCES ● AiiDA ● Ginestra™	match the outputs of the first block	**CHANNELS** ● AiiDA GitHub ● Marketplace ● INTERSECT/AiiDA website sites ● INTERSECT/AMAT newsletters ● INTERSECT/AiiDA social media activities ● INTERSECT targeted email	
COST STRUCTURE Personnel Travels Cloud/IT infrastructure Dissemination costs		**REVENUE STREAM (prospects)** Mixed free and proprietary software Ginestra™ → licensing fee Consulting fees		

Table 4. Business Model Canvas for the Ginestra-AiiDA interface.

Market	Source code license	Distribution strategy
Sector ● EDA Market **Segment** ● CAE ● TCAD, subsegment of IC physical design **End User market** ● Semiconductor ● Neuromorphic computing/AI	Open source. LGPL or GPL	Hybrid on premises and cloud based

Table 5. Market, source code license and distribution strategy for the Ginestra-AiiDA interface.

3.3 AiiDA-QE interface

Description

The AiiDA-QE interface permits accessing and automatically controlling (through AiiDA) the execution of complex quantum mechanical calculations performed with the QE suite.

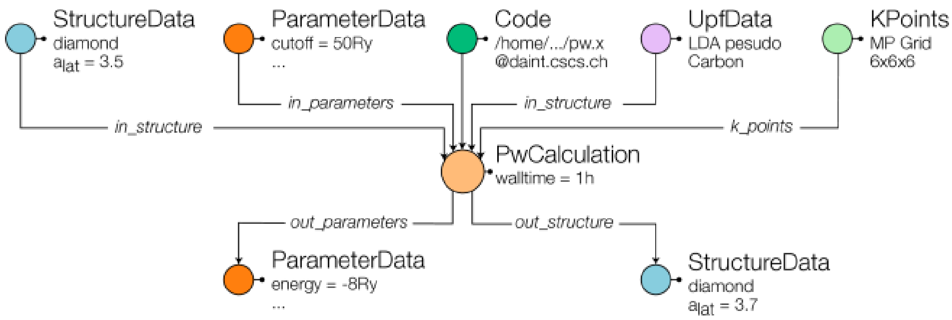


Figure 5. AiiDA-QE framework.

QE [1] is a suite of open-source codes for electronic-structure calculations from first principles, based on DFT, plane waves, and pseudopotentials.
Currently supported codes are:

- PW: Ground state properties, total energy, ionic relaxation, molecular dynamics, forces, etc.;
- CP: Car-Parrinello molecular dynamics;
- PP: Electronic structure analysis;
- PH: Phonons from density functional perturbation theory;
- TDDFPT: EELS and UV-vis absorption spectroscopy;
- GWW: many-body corrections;
- X-spectra: X-ray spectroscopy;
- Nudget Elastic Band (NEB): transition state barrier.

Business model

Free and Open Source Software (FOSS). This GPL software can be exploited for electronic-structure calculations and materials modeling consulting services.

Business model canvas

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITIONS	Stakeholder RELATIONSHIP	Stakeholder target SEGMENT
• QE foundation • CNR IOM • EPFL • MIT • Princeton	Development, maintenance and update of AiiDA-QE interface	• Ground state calculations • Structural optimization • Transition states and minimum energy paths • Response properties (Density Functional Perturbation Theory - DFPT), such as phonon frequencies, electron-phonon interactions and Electron Spin Resonance	• QE GitHub • AiiDA GitHub • Trainings for supporting the combination of the software usage	• EU industries working with molecular modelling and molecular dynamics

	KEY RESOURCES • AiiDA • QE	(EPR) and Nuclear Magnetic Resonance (NMR) chemical shifts • Ab initio molecular dynamics: CP and Born-Oppenheimer MD • Spectroscopic properties • Quantum import • Generation of pseudopotentials	**CHANNELS** • AiiDA GitHub • QE GitHub • Marketplace • INTERSECT/QE/ AiiDA website & social media activities • INTERSECT newsletter • Webinar • Conferences/Trade shows/R2B	• Scientific & Professional Communities
COST STRUCTURE Personnel Travels Cloud/IT infrastructure		**REVENUE STREAM (prospects)** Free and Open Source Software (FOSS) Consulting fees		

Table 6. Business Model Canvas for the AiiDA-QE interface.

Market	Source code license	Distribution strategy
Sector • EDA Market **Segment** • CAE **End User market** • Semiconductor • Neuromorphic computing/AI	GPL Open source	Cloud based

Table 7. Market, Source code license, and distribution strategy for the AiiDA-QE interface.

3.4 AiiDA-SIESTA interface

Description

The SIESTA program is able to perform, in a single run, the computation of the electronic structure, the optional relaxation of the input structure, and a final analysis step in which a variety of magnitudes can be computed: band structures, projected densities of states, etc. The operations to be carried out are specified in a very flexible input format [2]. AiiDA-SIESTA interface has been designed to run the most general SIESTA calculations through AiiDA workflows, with support for most of the available options (limited only by corresponding support in the parser).

Business model

Free and Open Source Software. This GPLsoftware can be exploited for electronic structure calculations and ab initio molecular dynamics simulation consulting services.

Business model canvas

<table>
<tr>
<td rowspan="2">KEY PARTNERS

● ICN2
● EPFL
● CSIC</td>
<td>KEY ACTIVITIES

Development, maintenance and update of AiiDA-SIESTA interface</td>
<td rowspan="2">VALUE PROPOSITIONS

● Total and partial energies
● Atomic forces
● Stress tensor
● Electric dipole moment
● Atomic, orbital and bond populations (Mulliken)
● Electron density
● Geometry relaxation, fixed or variable cell
● Constant-temperature molecular dynamics (Nose thermostat)
● Variable cell dynamics (Parrinello-Rahman)
● Spin polarized calculations (collinear or not)
● k-sampling of the Brillouin zone
● Local and orbital-projected Density Of States (DOS)
● Crystal Orbital Overlap Population (COOP) and Crystal Orbital Hamilton Population (COHP) curves for chemical bonding analysis
● Dielectric polarization
● Vibrations (phonons)
● Band structure.
● Ballistic electron transport under non-equilibrium</td>
<td>Stakeholder RELATIONSHIP

● SIESTA GitHub
● AiiDA GitHub
● Trainings for supporting the combination of the software usage</td>
<td rowspan="2">Stakeholder target SEGMENT

● EU industries working with molecular modelling and molecular dynamics
● Scientific & Professional Communities</td>
</tr>
<tr>
<td>KEY RESOURCES

● AiiDA
● SIESTA</td>
<td>CHANNELS

● AiiDA GitHub
● SIESTA GitHub
● Marketplace
● INTERSECT/ SIESTA/AiiDA website & media activity
● Webinar
● Conferences/Trade shows/R2B</td>
</tr>
<tr>
<td colspan="2">COST STRUCTURE

Personnel
Travels
Cloud/IT infrastructure</td>
<td colspan="3">REVENUE STREAM (prospects)

Free and Open Source Software (FOSS)
Consulting fees</td>
</tr>
</table>

Table 8. Business Model Canvas for the AiiDA-SIESTA interface.

Market	Source code license	Distribution strategy
Sector ● EDA Market **Segment** ● Computer-aided engineering CAE **End User market** ● Semiconductors ● Neuromorphic computing/AI	GPL Open source	Cloud based

Table 9. Market, Source code license, and distribution strategy for the AiiDA-SIESTA interface.

3.5 Properties Workflow

Description

Automated workflows for advanced on-demand materials properties (e.g., structural import data and relaxation, band structure calculation, determination of defect formation energy, computation of dielectric constants, and more).

Business model

Open Source Software. These workflows can be exploited for advanced materials characterization consulting services.

Business model canvas

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITIONS	Stakeholder RELATIONSHIP	Stakeholder target SEGMENT
● CNR ● EPFL ● ICN2+CSIC	Development of property workflow	Advanced Workflows for property calculation on-demand. ● Ground-state atomistic structure (relaxation) ● Total energy ● Electronic band structure ● Band gap ● Effective mass	● Ginestra™ simulation platform ● AiiDA GitHub ● Trainings for supporting the combination of the software usage	● EDA (Electronic Design Software) and more specifically the TCAD ● EU Semiconductor industries

		• Dielectric constant • Density of states • Defect formation energy • Chemical potential • Fermi energy Workflows to obtain required ground-state DFT quantities. Workflows to calculate the chemical potentials. Workflows to compute the desired corrections to the defect formation energy. Barrier energies for diffusion of defects (NEB workflow).		• Scientific & Professional Communities
	KEY RESOURCES • AiiDA • QE • SIESTA		**CHANNELS** • AiiDA GitHub • Marketplace • INTERSECT and partner websites & social media activities • Conferences/Trade shows/R2B	
COST STRUCTURE Personnel Travels Cloud/IT infrastructure		**REVENUE STREAM (prospects)** Free and Open Source Software (FOSS) Consulting fees		

Table 10. Business Model Canvas for properties workflow.

Market	Source code license	Distribution strategy
Sector • EDA Market **Segment** • CAE **End User market** • Semiconductor • Neuromorphic computing/AI	GPL Open source	Cloud based

Table 11. Market, Source code license, and Distribution strategy for properties workflow.

3.6 Analysis of complex systems

Description
Postprocessing tools for the analysis of disordered and amorphous materials from ab initio and classical atomistic simulations for material discovering and characterization of complex materials. Open Source Software.

Business model
Ab initio for advanced materials characterization consulting services.

Business model canvas

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITIONS	Stakeholder RELATIONSHIP	Stakeholder target SEGMENT
• CNR	Consulting **KEY RESOURCES** • AiiDA • QE • SIESTA • Classical MD	Atomistic modelling on-demand for: • Stoichiometry/local order • Materials characterization • Material optimization	• Consulting relations **CHANNELS** • INTERSECT and partners websites & social media activities • INTERSECT Newsletter • Scientific Journals	• EU Semiconductor industries • EU industries focused on nanomaterials • Scientific & Professional Communities
COST STRUCTURE Personnel Travels Cloud/IT infrastructure Dissemination costs		**REVENUE STREAM (prospects)** Free and Open Source Software (FOSS) Consulting fees		

Table 12. Business Model Canvas for the analysis of complex systems.

Market	Source code license	Distribution strategy
Sector ● Semiconductor ● Neuromorphic computing/AI	GPL Open source	Cloud based

Table 13. Market, Source code license, and Distribution strategy for the analysis of complex systems.

3.7 Semantic Workflow

Description

Semantic interfaces (wrappers) between simulation tools and OSP-core are the backbone of semantic interoperability enabling data/concept sharing and transfer between applications. They can be described as "bridges" in software development that enable the intercommunication between different tools, and the exchange of meaningful information (concept) understandable by any tool able to "speak" the same language. They are based on ontology-compliant high-level requirements. In INTERSECT, SimPhoNy [3] is the core of the semantic interoperability layer of IM2D that analyses the specific use case from user specification, identifies data and information that need to be exchanged, and selects the most appropriate workflow to be operated by the simulation Hub (sHub) through AiiDA.

Different wrappers facilitate the coupling-and-linking between different simulation engines and data sources. Using wrappers it is not necessary to translate the input and output formats from/to different simulation engines, while multiple simulations can be run and synced simultaneously to create complex scenarios, such as a multi-scale simulation.

Business model

Consulting services for ontology and semantic interoperability.

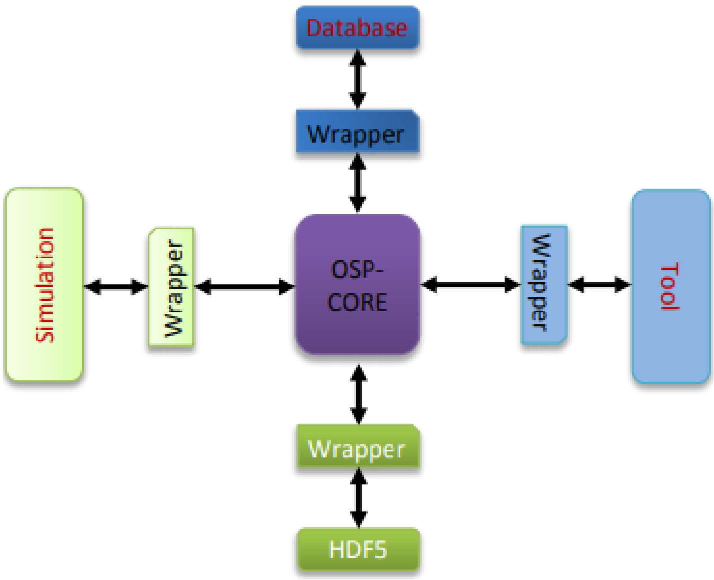


Figure 6. Semantic wrapper framework.

Business model canvas

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITIONS	Stakeholder RELATIONSHIP	Stakeholder target SEGMENT
• Fraunhofer IWM	Development, maintenance and update of semantic wrappers	Software interface between the core of (ontology-based) SimPhoNy and external software tools, for it significantly reduces the number of operations and efforts needed to develop advanced modelling applications, leading to significant savings in efforts and optimal use of R&D resources	• SimPhoNy GitHub • Trainings /consultancy	• EU industries working in materials domain (chemical, electronics) • Data-driven companies • Scientific & Professional Communities
	KEY RESOURCES		**CHANNELS**	
	• SimPhoNy		• SimPhoNy GitHub • Marketplace • INTERSECT/ SimPhoNy websites & social media activities • Webinars • INTERSECT newsletter	
COST STRUCTURE		**REVENUE STREAM (prospects)**		

Personnel Travels Cloud/IT infrastructure	Free and Open Source Software (FOSS)

Table 14. Business Model Canvas for the semantic workflow.

Market	Source code license	Distribution strategy
Sector ● EDA Market ● Semiconductor ● Neuromorphic computing/AI	GPL Open source	Cloud based

Table 15. Market, Source code license, and Distribution strategy for the semantic workflow.

4. Market research

According to the EMMC "White paper for business models and sustainability for materials modelling software" [4], the field of materials modelling covers a wide range of domains and subdomains such as computational chemistry, techniques based on quantum mechanics, continuum mechanics, statistical mechanics and thermodynamics, as well as fluid dynamics. It serves a wide range of industries, including fine and intermediate specialty and petro-chemicals, metals and alloys, ceramics, polymers, as well as applications in many fields such as automotive, aerospace, consumer goods, electronics, energy, and pharmaceutical development.

Since the main objective of INTERSECT is the development of material-based software for the development of disruptive electronics, our natural target segment is the **EDA** market.

4.1 EDA MARKET

The total EDA market is projected to be USD 20,318 million in 2027 compared to USD 9,190 million in 2020, with a Compounded Average Growth Rate (CAGR) of 8.28% [5]. Figure 7 shows the EDA growth by a quarterly basis from the Q4-2008 to the Q4-2020. In a decade, the EDA has doubled the revenues from USD 4,6 B to USD 9.2 B.

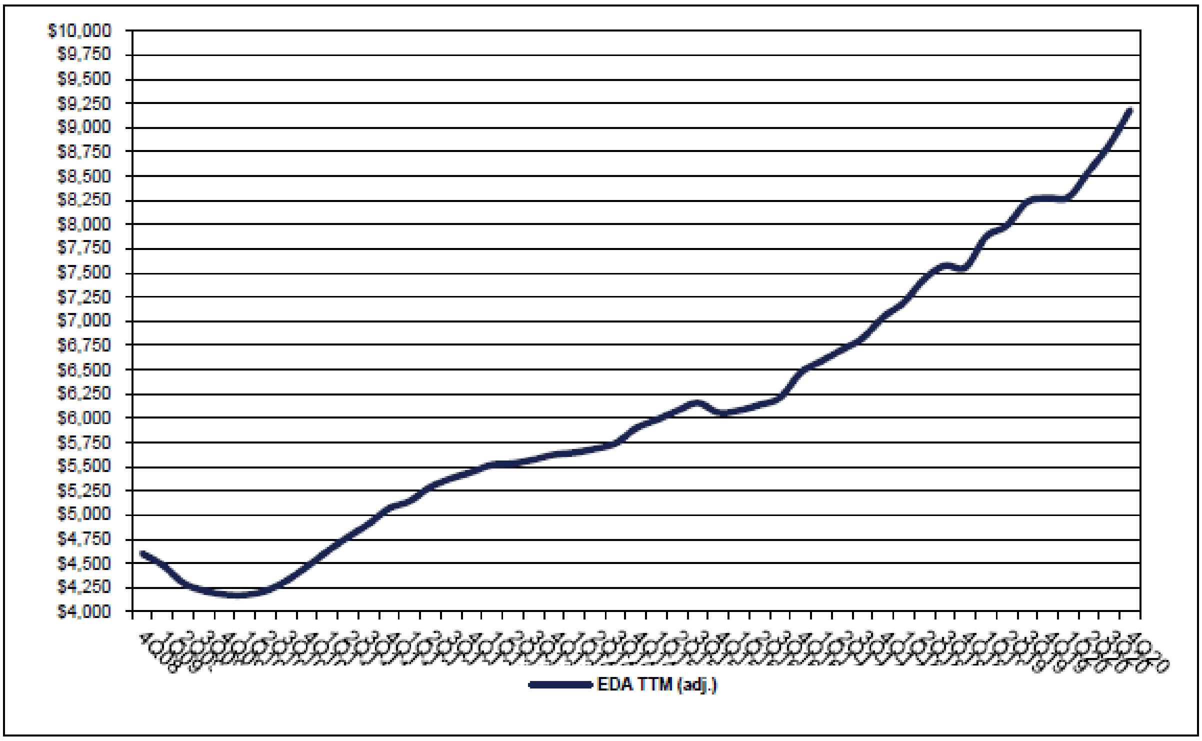


Figure 7. EDA, total revenue, 2008-2020. Source: ESDA, Griffin services 2020. [5]

EDA Market segmentation

According to the "2020 IBS report" [6], the EDA market segments and revenue growth are:

- The **CAE** category includes digital verification, emulation, analog, mixed-signal, and Radio Frequency verification. The CAE market is projected to be USD 6467 million in 2027 compared to USD 3251 million in 2018, with a CAGR of 7.94%.
- The **IC physical design** category includes physical design implementation and verification as well as silicon engineering such as Technology Computer-Aided Design (TCAD) and Design for Manufacturability (DFM). The IC physical design market is projected to be USD 3603 million in 2027 compared to USD 1936 million in 2018, with a CAGR of 7.14%.
- The **Printed-Circuit Board** (PCB) and **MultiChip Modules** (MCM) category include packaging design and verification for the substrates and multichip modules. The PCB/MCM market is projected to be USD 1678 million in 2027 compared to USD 847 million in 2018, with a CAGR of 7.90%.
- The **Semiconductor IP** (SIP) category includes the IP revenues within the EDA environment. The SIP market within the EDA ecosystem is projected to be USD 7929 million in 2027 compared to USD 3465 million in 2018, with a CAGR of 9.63%.
- The **Service** category includes support within the EDA design, security, and maintenance. The EDA service market is projected to be USD 641 million in 2027 compared to USD 434 million in 2018, with a CAGR of 4.43%.

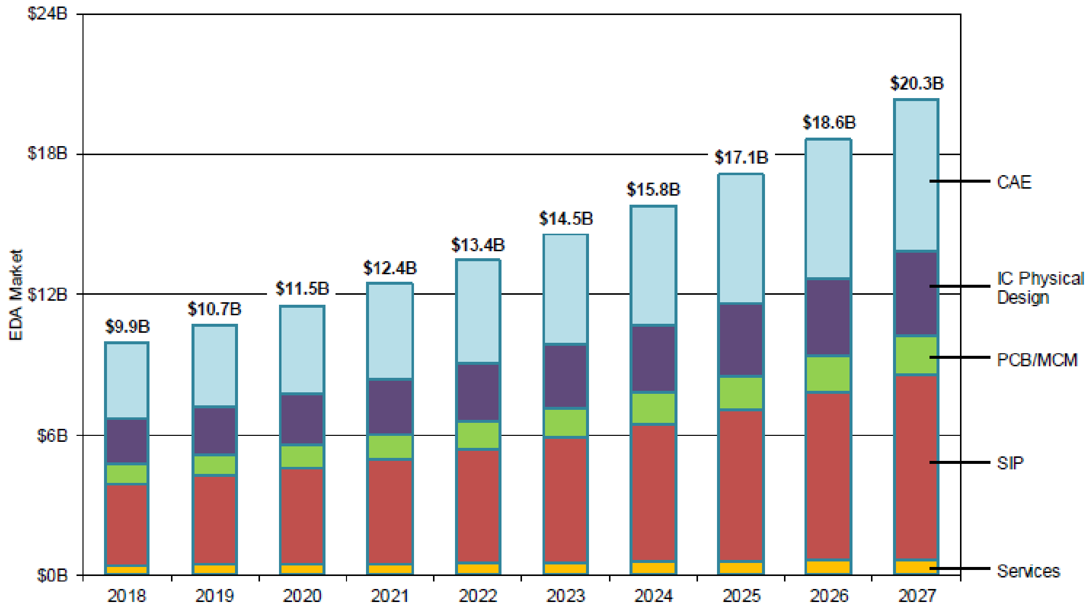


Figure 8. Revenue distribution for EDA segment. Source: IBS report 2020. [6]

Competitive landscape

EDA is an oligopolistic market dominated by Synopsys, Cadence, and Mentor (Big 3) that together own more than 88% of EDA market shares [5].

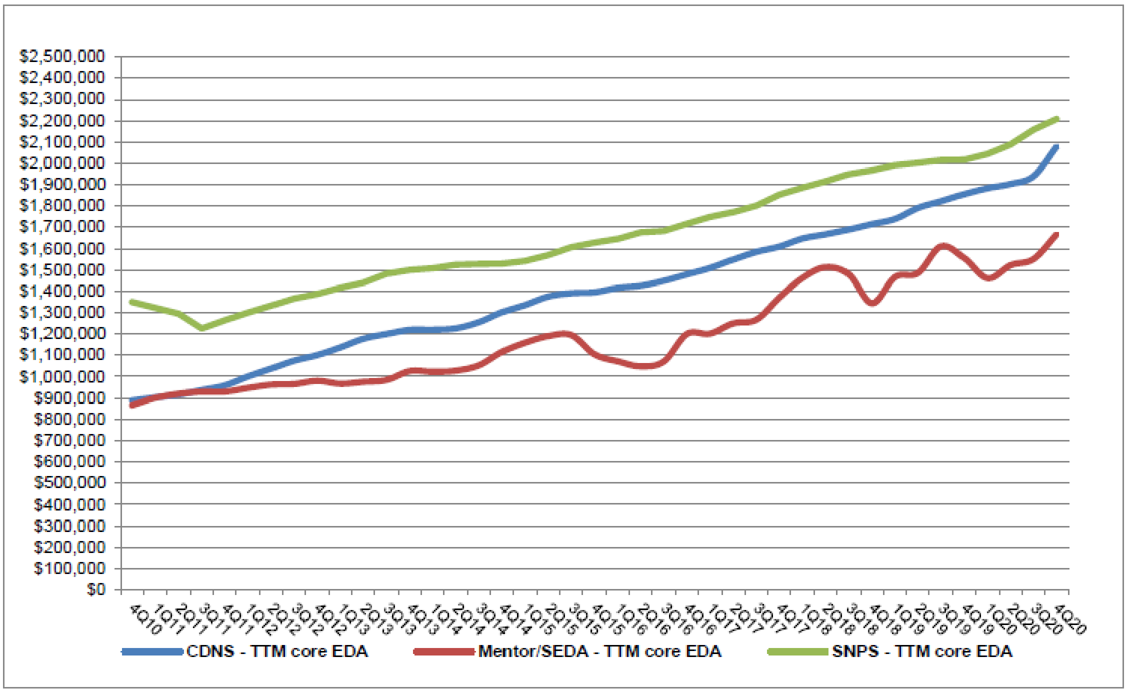


Figure 9. Big 3 EDA revenue growth during the last decade. Source: Griffin Securities report 2020. [5]

INTERSECT Positioning in EDA market

EDA market is the INTERSECT Total Addressable Market (TAM). In particular, CAE and IC physical have been identified as the most suited EDA segments to address to exploit the INTERSECT results. CAE and IC physical are the market segments of reference for estimating the potential TAM of IM2D and the Ginestra-AiiDA interface. The combination of CAE and IC physical design is projected to have a value of USD 10,070 million in 2027 compared to USD 5187 million in 2018, with a CAGR of 7.65% [6]. Following the EMMC white paper [4], the Served Addressable Market (SAM) of reference for the INTERSECT key exploitable results appears to be the global TCAD subsegment. Indeed, INTERSECT is providing innovative software/consulting solutions like the IM2D platform for helping both learning (i.e., understanding the device physics and material implications for process improvement) and material/device co-design (material screening, performance optimization).
In the next chapter we will describe the TCAD segment giving a revenue size overview, a stakeholder analysis, a competitive landscape, and finally the INTERSECT positioning.

4.1.1 TCAD Segment

The global TCAD market was valued at USD 247 million in 2020 and expected to reach USD 539.05 million by 2026, growing at a CAGR of 5.58% over the forecast period [7].

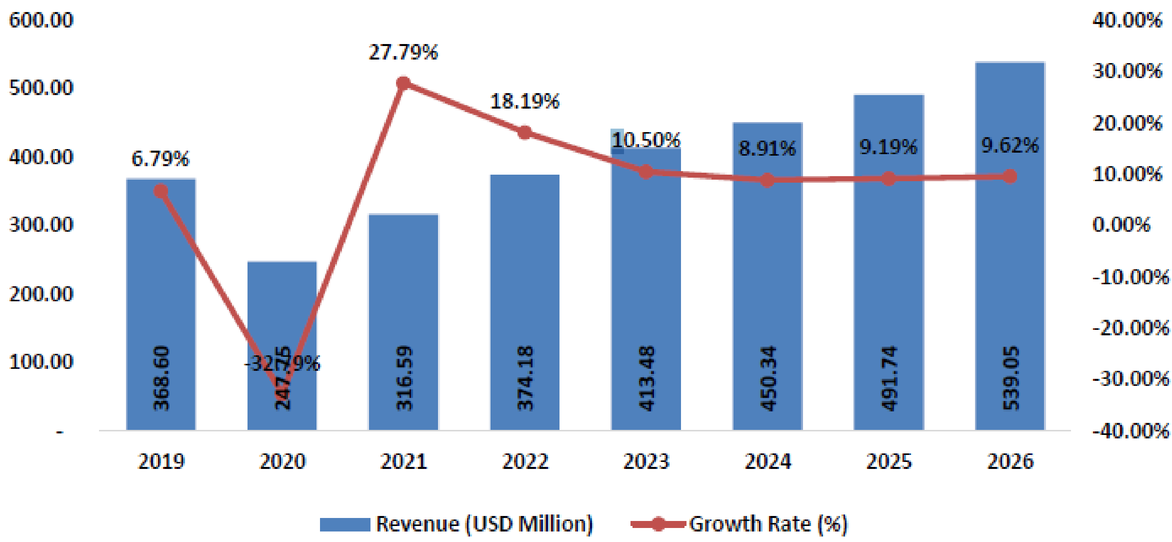


Figure 10. TCAD revenue forecast 2019-2026. Source: Fiormarkets report 2020. [7]

TCAD segmentation

According to Fiormarkets report 2020 [7], TCAD can be divided into two macro segments: (i) Conventional TCAD and (ii) Atomistic-TCAD.

(i) Conventional TCAD

Conventional or classical TCAD solutions are the synergistic combination of process, device and circuit simulation and modeling tools. Conventional TCAD market is projected to have a value of USD 2,163 million in 2026 compared to USD 1,597 million in 2019, with a CAGR of 4.63% [7]. The conventional TCAD starts from the physical description of integrated circuit devices, considering both the physical configuration and the related device properties, to extract the key parameters that support circuit design and statistical metrology. Design rule development, extraction of compact models, and more generally design for manufacturability process are key tools that Conventional TCAD uses to solve device modeling challenges that support intrinsic device scaling and parasitic extraction design.

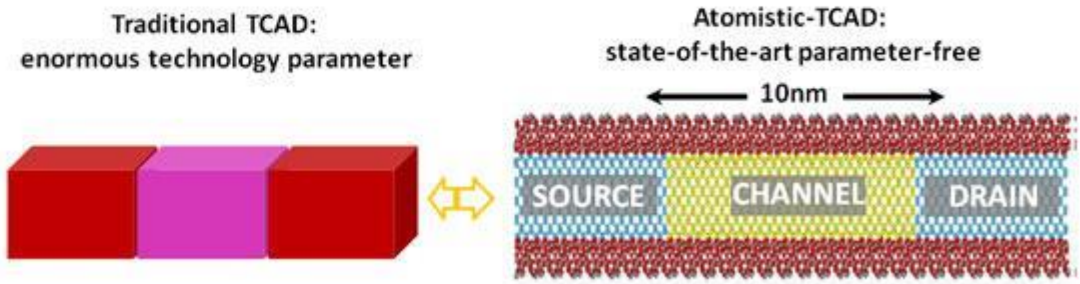


Figure 11. Traditional vs Atomistic-TCAD. [7]

(ii) Atomistic-TCAD

Atomistic-TCAD is one of the most advanced and accurate TCAD software for designing atomistic electronic devices in the world, based on the atomic-level simulation. Atomistic-TCAD market is projected to have a value of USD 1,498 million in 2026 compared to USD 1,131 million in 2019, with a CAGR of 4.3% [7]. Atomistic-TCAD software aims at helping semiconductor manufacturers to solve the design problems for sub-20nm-device technology, as it is a computer-aided design software that works at the atomic level, and can obtain the process technology parameters precisely, without heavy experimental measurement, by modeling and simulating nano-scale semiconductor electronic devices.

	2019	2026	CAGR (2020-2026)
Conventional TCAD	1,597.05	2,163.48	**4.63%**
Atomistic TCAD	1,131.12	1,498.60	**4.30%**
Total	**3,724.46**	**4,980.40**	**4.44%**

Figure 12. Global Technology Computer-aided Design (TCAD) Market Revenue (Million USD).

Regional Analysis

Analyzing the TCAD market revenue by region, the main customers are based in the US and Asia-Pacific. Nonetheless, Europe has a relevant position representing 30% of the total TCAD revenue, driven by sectors like automotive, mobility (rail, air), and engineering [7].

	2019	2026	CAGR (2020-2026)
North America	152.38	221.33	**5.48%**
Europe	75.34	111.31	**5.73%**
Asia-Pacific	111.32	169.21	**6.16%**
South America	17.58	22.32	**3.47%**
Middle East and Africa	11.98	14.88	**3.14%**
Total	**368.60**	**539.05**	**5.58%**

Figure 13. Global Technology Computer-aided Design (TCAD) Market Revenue by region (Million USD). Source: Fiormarkets 2020 [7].

Competitor Landscape

As for the whole EDA market, the TCAD market segment is a monopolistic market led by Synopsys (59%) [7].

Competitor	Revenue 2019 (M$)	Market share %
Synopsys	218.78	59%
Silvaco	32.34	9%
Crosslight	4.43	1%
Global TCAD	3.75	1%
Coventor	6.1	2%
Others	103.2	28%

Table 16. TCAD competitor landscape.

4.1.2 Stakeholders analysis

TCAD principal stakeholders are: Integrated Device Manufacturers (IDM), Foundries, Fabless, and Academia [7].

Integrated Device Manufacturers and foundries represent 70% of the TCAD customers.
An IDM is a semiconductor company which designs, manufactures, and sells integrated circuit (IC) products. As a classification, IDM is often used to differentiate between a company that handles semiconductor manufacturing in-house, and a fabless semiconductor company, which outsources production to a third party. These companies make a large use of TCAD in order to design innovative IC products. STMicroelectronics, Infineon, NXP, Nexperia, and Global Foundries are examples of European-based IDMs.

Fabless Semiconductor Companies represent 27% of TCAD customers.
By definition, the term "fabless" means that the company designs and sells the hardware and semiconductor chips but does not manufacture the silicon wafers, or chips, used in its products, whose fabrication it outsources to a manufacturing plant or foundry. The TCAD is used in the designing by the Fabless Semiconductor Companies, less than 5% of which are located in Europe.

Academia represents 3% of the TCAD customers.
Even though academia represents a small business for TCAD, there are many scientific communities working in the materials modeling domains who take advantage of it. For example, a great part of the most reputed engineering universities or research centres use TCAD to teach and train students.

INTERSECT positioning

The growth of the global TCAD market is majorly driven by an increasing number of technical innovations and overall digital transformation in numerous industries throughout the world. As shown above, Europe represents 30% of the total TCAD demand. Automotive, IoT, and Neuromorphic AI applications will push the simulation growth in the next few years.

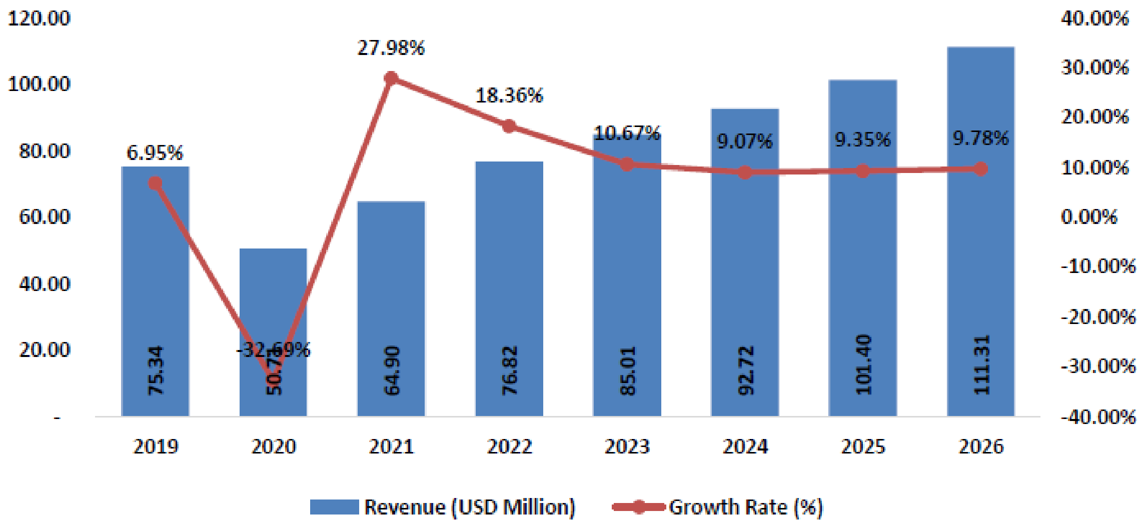


Figure 14. Global Technology Computer-aided Design (TCAD) Market Revenue by region (Million USD). Source: Fiormarkets 2020 [7].

INTERSECT's intent is to sustain and develop a European materials-modelling ecosystem to connect the simulation providers, scientific communities, semiconductor, and other strategic tech-companies, including SMEs or startups, that may suffer the competition with electronics giants from US or Asia. The INTERSECT project conjugates the advantages of both material and device-driven software, joining the properties of materials at the atomistic level with the electrical behaviour of devices, including variability and reliability at the statistical level. INTERSECT's IM2D platform aims at enhancing the European Atomistic-TCAD position by offering a set of top-down and bottom-up solutions to answer for the material modeling and device optimization demand in the European ecosystem.

4.2 End Market applications

4.2.1 Semiconductors

Despite the global pandemic and resulting economic downturn, the semiconductor industry has remained resilient, ending 2020 with revenue growth of 6.8% [8]. Global semiconductor sales exceeded USD 466 billion. In March 2021, global semiconductor sales reached a total of USD 41.05 billion, rising up from the USD 39.59 billion in February 2021.

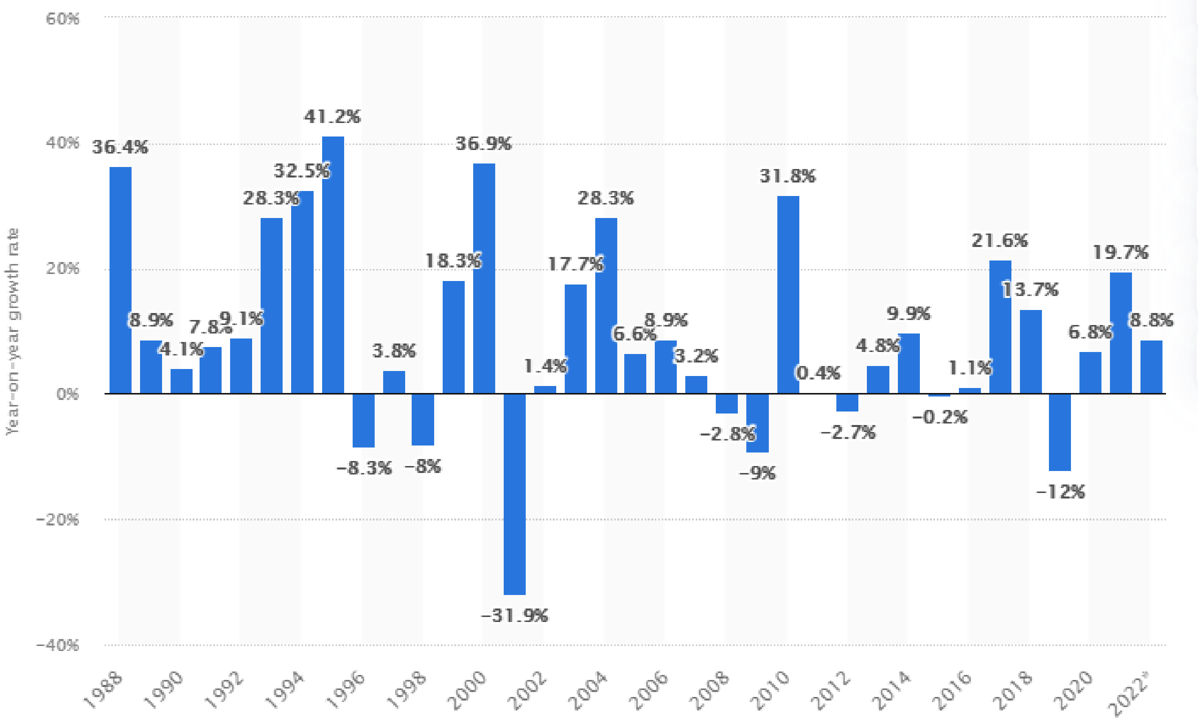


Figure 15. Forecast revenue growth rate global semiconductor industry 1988-2022. Source Statista.com. [8]

Regional analysis

Global Market

Semiconductor consumption in China is projected to be USD 621.2 billion in 2030 compared to USD 253.1 billion in 2018, with a CAGR of 7.77% [9]. China market is projected to represent 59.01% of the global semiconductor consumption in 2030 compared to 52.99% in 2018. Even though Chinese companies continue to build up semiconductor supply, the dominant percentage of the China market share in 2020-2030 will come from foreign supply.

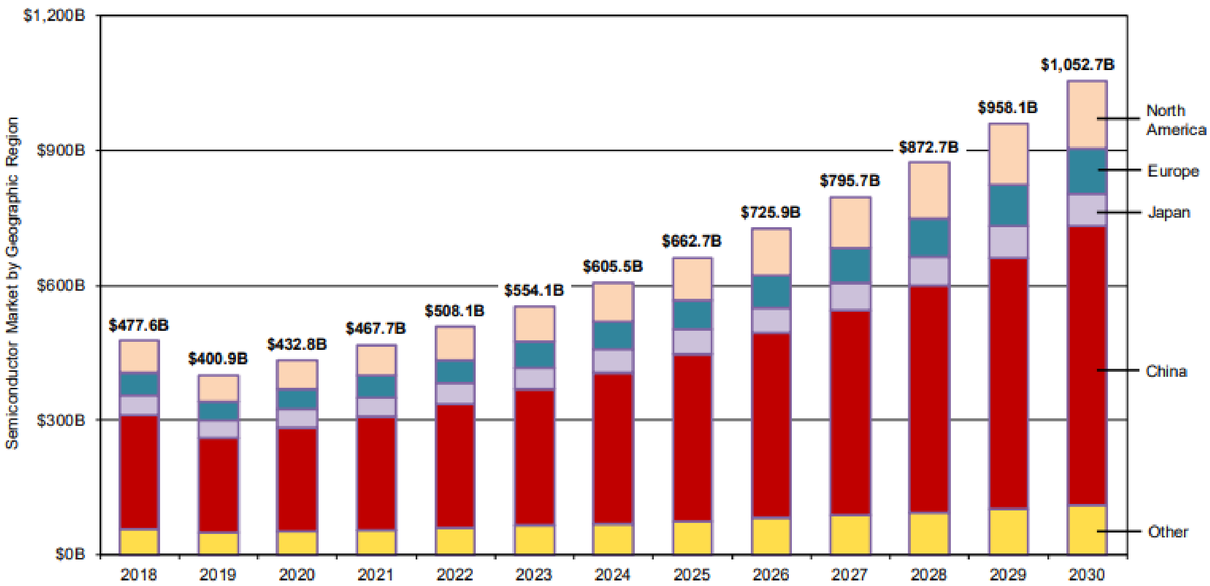


Figure 16. Semiconductor Market by Geographic Region. Source: IBS report 2020. [9]

European Market

The consumption of semiconductors in Europe is projected to be USD 100.7 billion in 2030, compared to UD 49.0 billion in 2018, indicating a CAGR of 6.18%. The European market is projected to represent 9.57% of global semiconductor consumption in 2030, compared to 10.27% in 2018. Semiconductor consumption in Europe is projected to have an annual growth of 7.12% in 2030, with a value of USD 44.7 billion [9]. As reported in the KPMG Semiconductor Industry survey 2021 [10], due to smartphone growth, Internet of Things (IoT), Artificial intelligence (AI), and Automotive development, the semiconductor revenue and innovation expansion will be driven by wireless applications in the next few years. Nonetheless, the automotive industry continues to be the largest user of semiconductors in Europe, as European automobile companies are adopting many new technology features and are leaders in manufacturing and selling in global markets.

"*The connected and autonomous vehicles of the future are effectively supercomputers on wheels requiring dramatically higher chip content and driving greater convergence of the automotive and semiconductor industries,"* says Gary Silberg, KPMG Global Automotive Sector Leader [10]. Automakers develop more and more advanced & connected, electric vehicles. New research is done in the field of self-driving vehicles, whose reliable infrastructure is enabled by 5G, artificial intelligence, and cloud developments. Thus, the sector is poised to remain prominent as a buyer of semiconductor products for years to come.

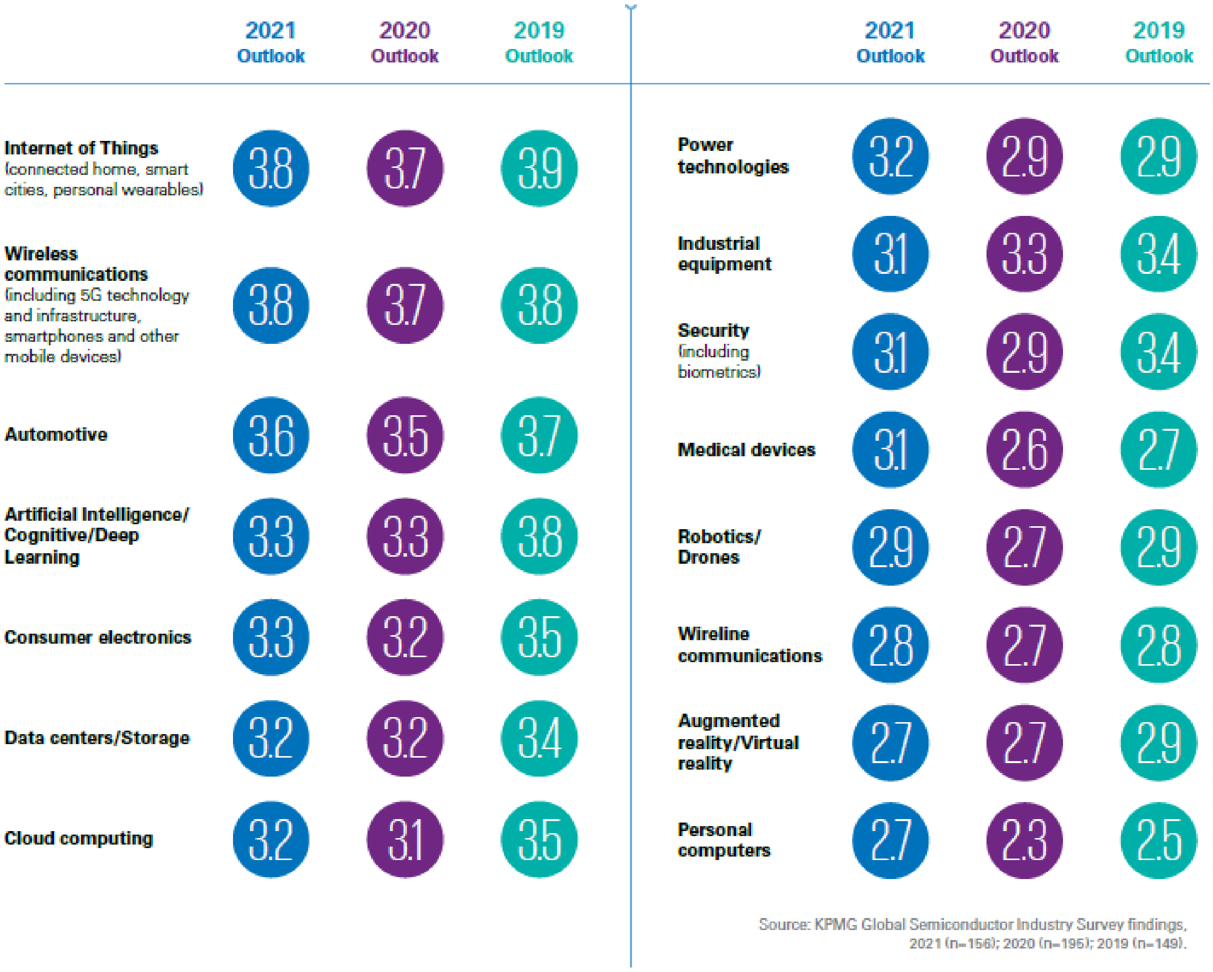


Figure 17. Applications driving semiconductor company revenue over the next year. Source: KPMG Semiconductor Industry survey 2021. [10]

4.2.2 Neuromorphic computing

Nowadays, there is a strong need for power-efficient technologies to handle the increasingly demanding AI workloads, and the growing amount of data generated worldwide in a sustainable manner. Neuromorphic technologies – inspired by biological brains – are a promising answer to this need as they can perform challenging AI tasks very efficiently. The total neuromorphic market is expected to reach USD 22B in 2035. The three main segments will be consumer, industrial and automotive. Automotive applications represent the greatest opportunity, reaching a potential market of USD 9.5 B by 2035. [11]

$B	2025	2030	2035
Mobile	0.05	2.0	3.8
Client PC &Tablet	-	0.1	0.7
Other consumer	0.01	0.7	1.6
Automotive	0.01	2.0	9.5
Medical	-	0.01	0.3
Industrial	0.14	2.0	4.0
Data center	-	0.7	2.0
Total	0.2	7.5	22.0

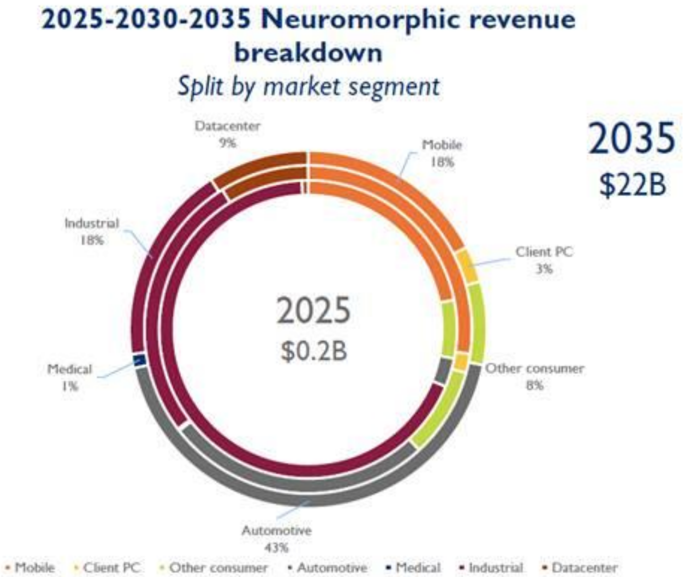


Figure 18. Neuromorphic revenue breakdown split by market segment. Source: Yole Développement. [11]

Neuromorphic computing ecosystem

The neuromorphic ecosystem is today very dynamic with three main categories of players: university & research institutes, labs affiliated with large companies, and start-ups. The latter are the first players to bring products to the market for edge computing, targeting industrial, automotive, and consumer applications.

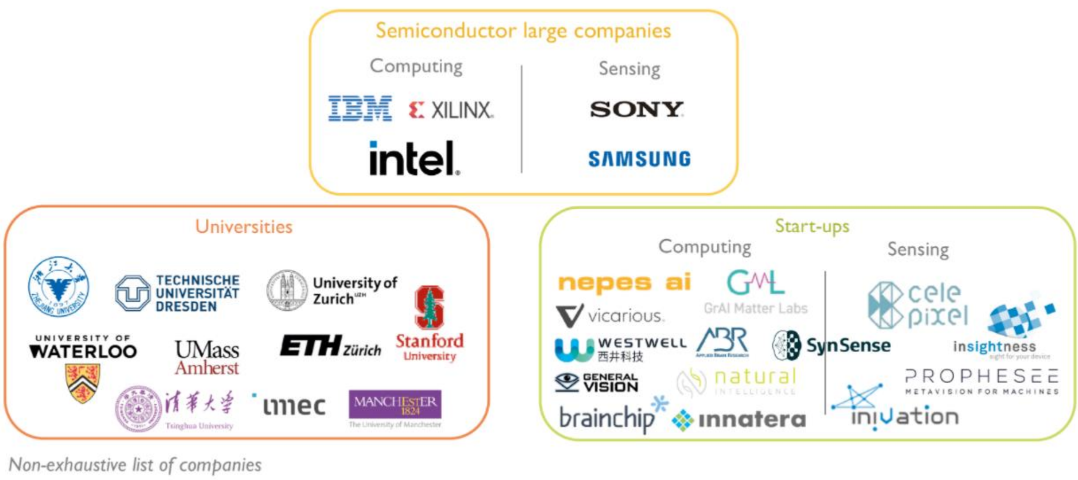
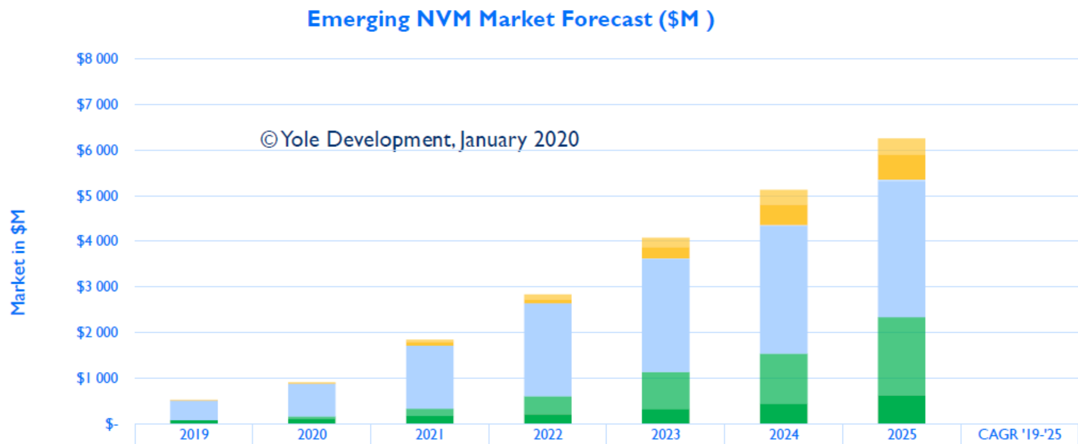


Figure 19. Neuromorphic computing ecosystem. Source: Neuromorphic Computing and Sensing 2021 report, Yole Développement [11].

INTERSECT Positioning

INTERSECT's key results will support the future development of a new class of storage-class memory elements (such as memristors, PCM, RRAM and FeRAM), which will contribute to innovate the largest and most promising sector of the neuromorphic market. The memristors market was valued at USD 2432.68 million in 2020 and is expected to reach USD 37431.22 million by 2026 and register a CAGR of 52.7% during the forecast period 2021-2026 [12]. Memristors are expected to become a mainstream product by the end of the 2030. IM2D platform can be exploited for improving memristors device power saving, performances, bandwidth requirements, and space-saving augmented with data transfer rate. Semiconductor players are also considering the adoption of emerging non-volatile memories assembled in crossbar arrays, leveraging the "synapsis-like" properties of resistive memories (e.g., PCM, OxRAM, CBRAM). The overall emerging memory market will grow at a CAGR 2019-2025 ~ 51% [13].



	2019	2020	2021	2022	2023	2024	2025	CAGR '19-'25
Total Market (in $ M)	$522	$902	$1 837	$2 833	$4 078	$5 132	$6 260	51%
Total Embedded Market (in $ M)	$20	$74	$218	$505	$1 072	$1 477	$2 120	118%
Total Stand-Alone Market (in $ M)	$502	$829	$1 619	$2 329	$3 006	$3 655	$4 140	42%
Embedded RRAM	$10	$21	$51	$110	$216	$329	$365	82%
Stand-alone RRAM	$5	$11	$77	$84	$234	$445	$542	120%
Embeddded PCM	$-	$-	$-	$-	$31	$34	$38	0%
Stand-alone PCM	$433	$715	$1 383	$2 039	$2 467	$2 788	$2 981	38%
Embedded MRAM	$10	$52	$167	$395	$825	$1 114	$1 717	137%
Stand-alone MRAM	$65	$103	$159	$206	$305	$421	$617	46%

Figure 20. Emerging Non-Volatile Memories Market Forecast. Source: Yole Développement 2020. [13]

Phase Change Memory (PCM) will lead the growth of emerging memories thanks to its cost/performance ratio for applications in persistent memory and low-latency storage. European players, like STMicroelecronics, are investing in PCM technologies for automotive applications. Starting from the WP3 use-case applications, INTERSECT solution will be able to significantly contribute to develop a new class of devices that can bring the neuromorphic computing from a niche to mainstream applications as expected by Yole Développment in the upcoming years.

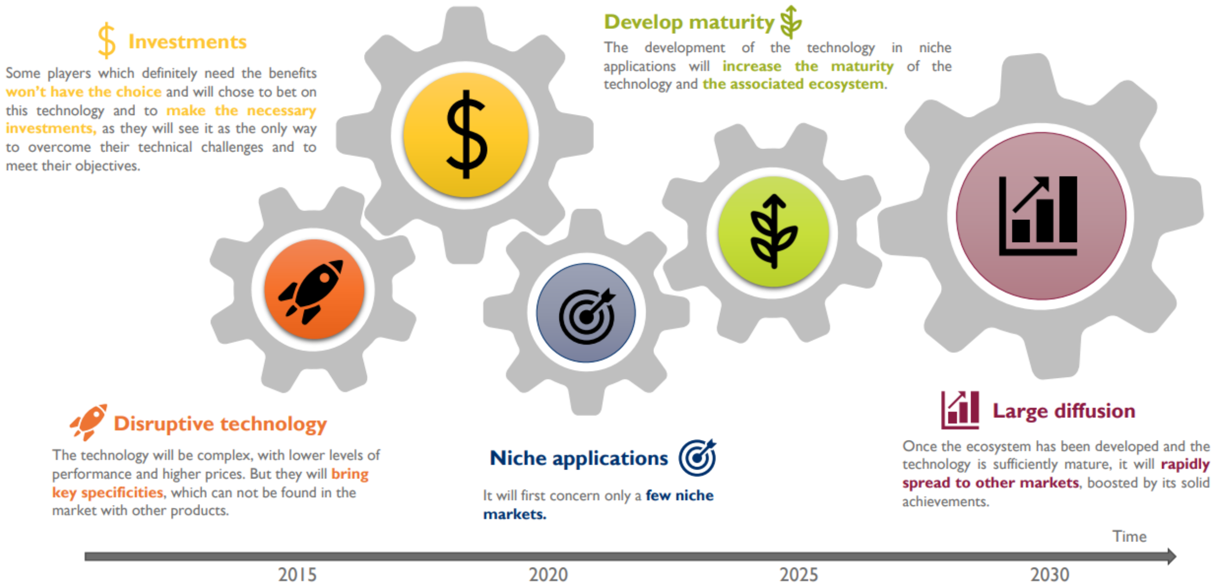


Figure 21. Neuromorphic computing evolution. Source: Yole Développement 2020. [11]

4.3 Market trends and opportunities

4.3.1 EDA

Increasing complexity

The increasing complexity of the semiconductor products requires a parallel increasing investment on advanced EDA tools. Scaling down the device to a few-nanometer scale requires a quantum mechanical understanding of materials and of atomic defects. IM2D and other sophisticated modelling solutions (e.g., based on atomistic quantum mechanical models) are able to catch the complexity of advanced materials. Exploiting INTERSECT solutions, atomic-scale material properties, temperature response, charge, and ion transport phenomena are incorporated into a device level description allowing to handle technology issues, device geometry, integration, and biasing scheme.

Increase costs of design

The analysis of the design costs shows that the cost of the R&D staff represents 75% of the total cost of implementation of the design, while the computer costs are only 5%, and the cost of EDA tools represents 20% of the total [6]. In future projections, EDA tools and computer power scale up to 80% of the total cost, and the design personnel represents 20% of the total. With respect to this, INTERSECT may offer a competitive hybrid solution, that is partially proprietary (Ginestra^{TM}) and partially free and Open Source that can reduce the financial impact of EDA tools in the future design.

Design Cost Segmentation for Typical Design at 7nm (Source IBS report 2020)		
%	Present	Future
EDA tools	20	50
Design engineers	75	20
Computer power	5	30
TOTAL Design cost	100	100

Table 17. Design Cost Segmentation for Typical Design at 7nm. Source: IBS report 2020. [9]

Expansion of the customer base for EDA tools

System companies such as Google, Amazon, Facebook, Microsoft, Alibaba Group, Baidu, and others want access to semiconductor design capabilities, following the success of Apple in getting tailor-made semiconductors from the manufacturing companies [6]. Similarly, a number of automobile companies yearn for their own design capabilities to support autonomous driving and other data processing activities required in the transportation ecosystem. Thanks to a user-friendly Graphical User Interface (GUI), a highly-automated workflows and semantic interoperability layer, IM2D can be used by a large number of stakeholders with different levels of knowledge and coming from different fields. This flexibility is pivotal to bring materials modelling to the heart of industrial business decision-making levels. As it is, it allows industries to rapidly build custom-designed integrated materials-modelling apps and data-driven business decision systems, concurrently reducing the costs and the time to market.

Cloud-based EDA tools

The use of cloud computing, machine learning, and AI can result in a large increase in the number of new products being developed every year in both advanced features and mature technologies. Big players like Cadence Design Systems, Synopsys, Mentor Graphics, and ANSYS already provide some EDA tools online. Their initial approach is to support higher-throughput cloud computing. IM2D and other key exploitable results are connected to Materials Cloud, a cloud-based database in which a customer can empower data-based discovery and access cloud or redeployable simulation services, like AiiDA Lab, in a FAIR compliant way. This offers a cloud platform where end users can launch and monitor AiiDA workflows, and analyze the results.

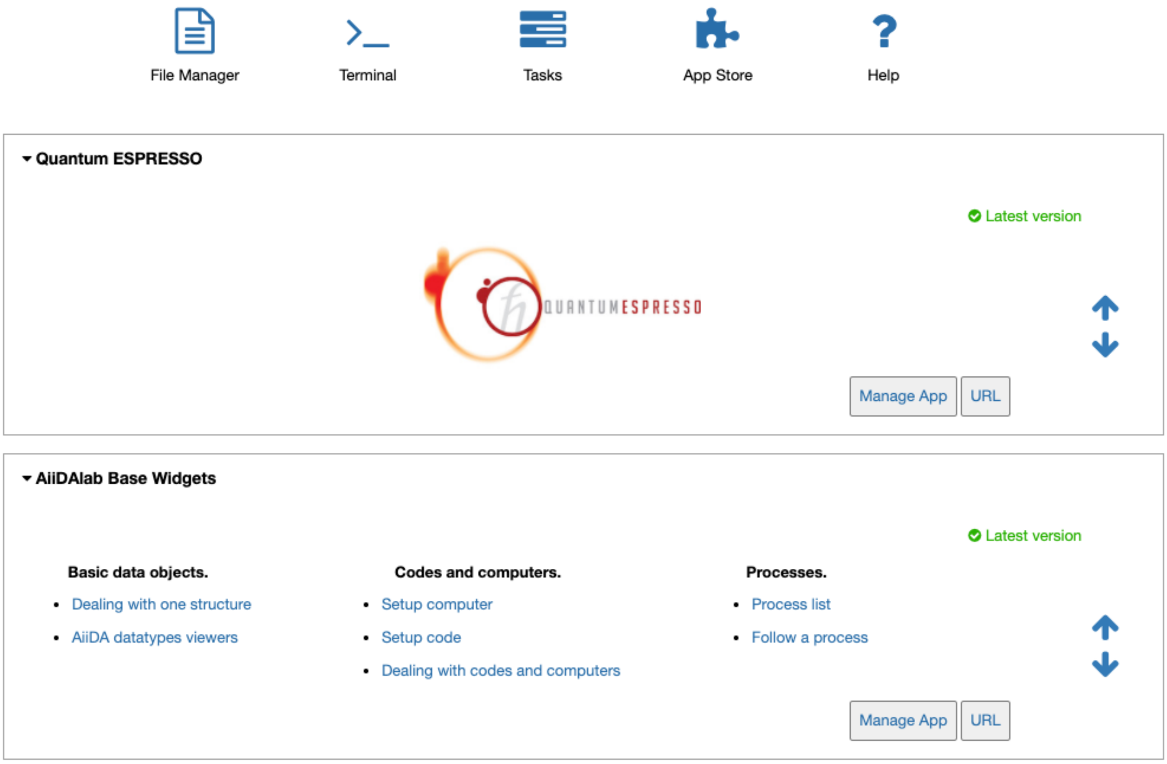


Figure 22. AiiDA Lab on Materials Cloud. [14]

Increased use of AI

New-generation EDA tools will adopt more AI capabilities and will use machine-learning technology to improve design productivity. In this field, for example, Cadence provides massively parallel computing support capabilities; Synopsys will continue to promote its fusion compiler capabilities. In INTERSECT, machine-learning techniques are used within OPTIMADE API to access material databases and calculate the materials properties in real time.

4.3.2 Semiconductors

Oligopoly Market

Moore's law has guided the global semiconductor industry for the past decades (since 1965), improving both performance and cost through node scaling. After 2002 (130nm), the industry has been consolidating extensively. Limitations in scaling have disrupted several companies that were competing in this business and, presently, the market has turned into an oligopoly, with just a handful of key players remaining.

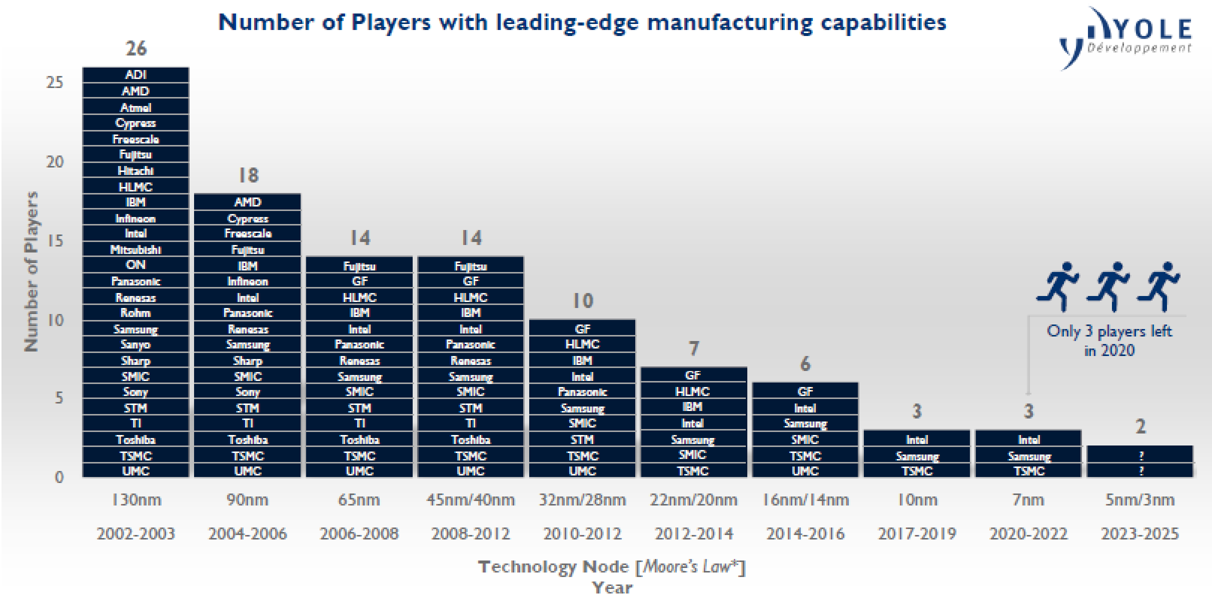


Figure 23. Semiconductor Player by Technology. Source: Yole Développement. [11]

R&D investment, costs and efficiency

Innovation investment is consistently a top line item on semiconductor budgets. Research and development spending by semiconductor companies worldwide is forecasted to grow 4% in 2021 to USD 71.4 billion, after rising 5% in 2020 to a record peak of USD 68.4 billion, according to IC Insights' new 2021 edition of *The McClean Report* [15]. Total R&D spending by semiconductor companies is expected to rise by a CAGR of 5.8% between 2021 and 2025 to USD 89.3 billion. R&D as a percentage of worldwide industry sales slipped to 14.2% in 2020 compared to 14.6% in 2019, when R&D spending declined 1% and total semiconductor revenue fell 12%. *The McClean Report* shows that the top 10 R&D spenders (Intel, Samsung, Broadcom, Qualcomm, Nvidia, TSMC, MediaTek, Micron, SK Hynix, and AMD) collectively increased their research and development expenditures by 11% in 2020 to USD 43.5 billion, which was 64% of the industry's total.

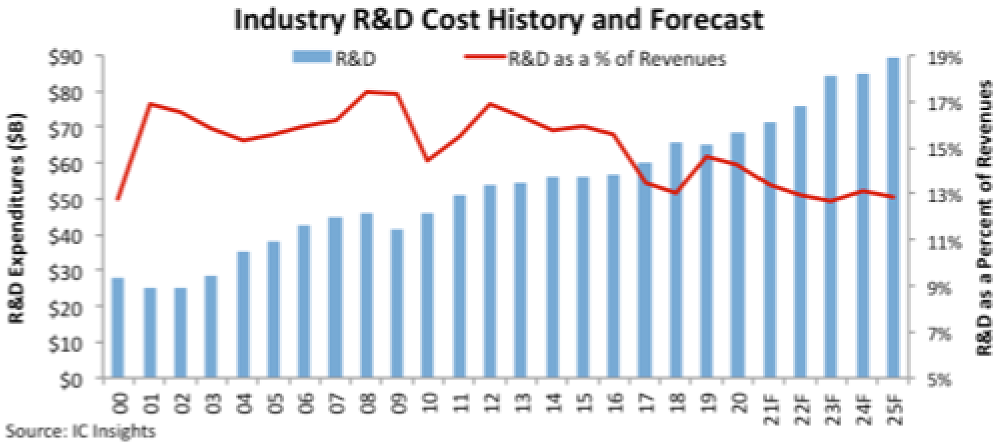


Figure 24. Industry R&D costs from 2000 to 2025. Source: IC Insights 2020. [15]

According to the *2021 KPMG Global Semiconductor Industry Survey* [10], the semiconductor industry reports significant efficiency in R&D, a key driver of profitability growth. Two-thirds of respondents (66%) say their companies' R&D roadmap is well aligned with market opportunities. While this represents an encouraging figure, a significant opportunity remains for one third of industry players.

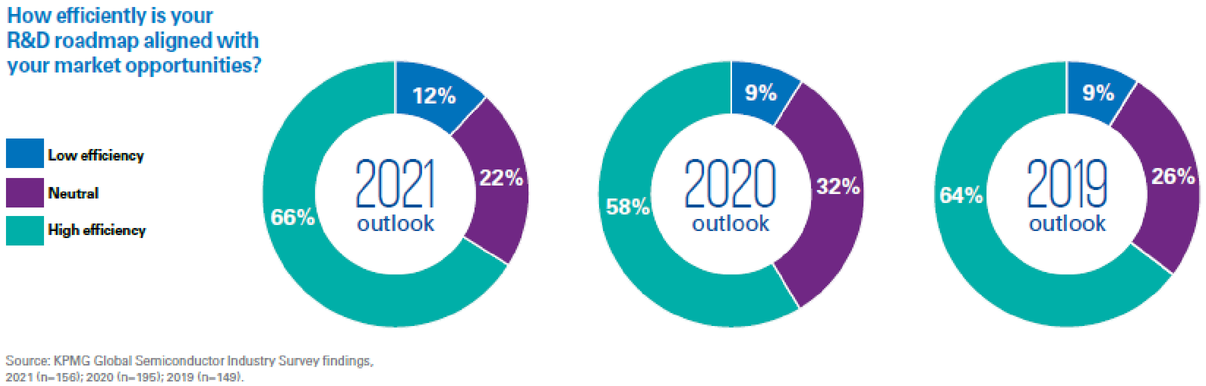


Figure 25. Global Semiconductor Companies R&D efficiency survey. Source: KPMG Global Survey 2021 [10]

KPMG survey reports also the top semiconductor industries priorities for the next three years. Executing on growth initiatives (including diversifying and expanding R&D) is the biggest strategic priority for semiconductor companies over the next three years. It was selected as a top three in importance by 68 percent of respondents. INTERSECT key exploitable results (D4.8) are developed for accelerating the learning and the design of advanced complex materials and innovative devices for application in emerging electronics (e.g. synaptic electronics and neuromorphic computing), which can enable new opportunities for the AI, IoT and Automotive applications.

Talent development and shortage

The industry demonstrated a high level of resilience to get through 2020 intact; now companies are ready to take strategic action to sharpen long-term competitiveness. In this frame, developing and managing talents still represent a top priority for semiconductor industries.

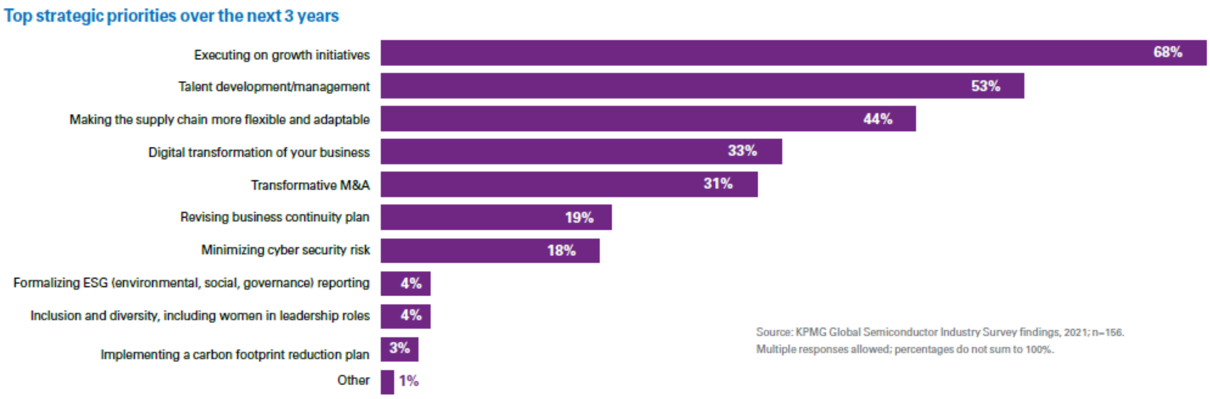


Figure 26. Top strategic priorities for Semiconductor Industries. Source: KPMG Global Survey 2021. [10]

With a shortage of technically-skilled workers already existing, the worldwide demand for more innovative technology products and solutions in the wake of COVID-19 will only exacerbate the problem. The possibility of having solutions that are usable both on premises and on cloud, plus the virtual work model experiences during COVID-19, have helped companies to solve this shortage problem: they have developed plans for permanent work-from-anywhere options in order to cast a wider talent net, improve collaboration across distances, and boost productivity.

INTERSECT in a way can help face these setbacks: as mentioned before, thanks to the ontology and the semantic wrappers development, it can offer highly-automated materials and device design solutions, tailored on the knowledge level of the final users (*persona*). This is conceived to enlarge the audience with respect to the conventional EDA tools. Nonetheless, INTERSECT offers hybrid *on prem-cloud* solutions that can easily work in conventional laptops from anywhere. This is also aligned with the huge digital transformation effort that the companies are doing after the global pandemic period.

Data-driven business decision systems

Data insights are a critical component of enhanced supply chain resiliency. Using technology and applications to collect granular data and metrics at all points of the supply chain enables semiconductor companies to make faster and data-driven decisions. INTERSECT solutions enables data-driven business decision systems to assist rapid and efficient decision making *i)* by determining the critical data points at each milestone in each product development processes; *ii)* by establishing an agnostic and adaptable platform to gather essential data, make a predictive analysis and drive business decision making and, *iii)* by establishing a device performance scorecard and baseline that can then be used for future continuous improvements and process optimization.

5. SWOT analysis

Figure 27. SWOT analysis.

Strength:

- **Accelerate Time to market:** shortened design, continuous integration and validation cycles enabled by IM2D platform;
- **Improve R&D efficiency**: cost-savings, more efficient use of R&D resources and prioritization of the most important programs, especially within Agile R&D approaches;
- **Improve R&D know-how**: high automation and semantic interoperability level of IM2D contributes to reducing staff cost;
- **Increase productivity:** IM2D contributes to increase the productivity empowering faster cycles of learning generated from the design databases across various teams and locations;
- **Enhance Innovation on emerging technologies**: materials discovery capability of IM2D allows an easier exploration of the material workspace from an electronic device-oriented industrial perspective;

- **Foster integration and interoperability**: close integration with pre- and post-manufacturing steps for two-way data exchange (material-to-device and device-to-material) for device optimization;
- **Enable data driven decision-making**: end-users can gain greater insight into risk and delays, enabling proactive decision making to manage resources and customer commitments.

Weaknesses

- **Pre-competitive solution:** since the final goal of the project is to deliver a "pre competitive" product at the end of it, the device will not be market-validated enough for distribution to end customers;
- **Quality of the product:** since most of the IM2D platform and other key exploitable results rely on academic softwares, the overall quality of the software may be not competitive enough with the commercial solutions.

Opportunities

- **High demand from end users**: as described in the market section, EDA demand is growing mainly due to new entrants like system and automotive industries;
- **Increasing of R&D investments in emerging technologies:** emerging technologies will play a crucial role for the neuromorphic, AI, IoT, and electric vehicle market;
- **Increase AI adoption:** machine learning techniques are used within the INTERSECT project;
- **Cloud based solutions:** most of EDA tools are moving to cloud solutions; IM2D is moving in this direction and offers a hybrid *on prem-cloud* solution;
- **Talent shortage:** INTERSECT strives to enlarge the end user base thanks to the semantic interoperability with the goal of spreading the materials and device modeling practice in the semiconductor industries.

Threads

- **Oligopoly Market**: EDA is dominated by Synopsys, Cadence, and Mentor;
- **Industrial stakeholder skepticism**: semiconductor industries are reluctant to implement new software solutions that are not yet market validated; they are extremely sensitive to Intellectual Property (IP);
- **Switching costs:** despite the companies always scout for innovative solutions, testing a new software requires a significant investment; they are extremely selective on implementing new software in their environment.

6. Exploitation Strategy

6.1 Exploitation of knowledge

As we described in the D4.3, one of the main commercial values of the INTERSECT project is the know-how. Within the project the IP management is carried out by the Project Coordinator and the Governing Board. During the innovation Scouting phase (as presented in D4.8 “Innovation management assessment and revision”, M31), an IP register has been created to track the background and foreground IP in the INTERSECT consortium. As specified in the Consortium Agreement, the partners involved in singular tasks will manage the relevant IP exploitation.

6.2 Exploitation of software key results

In most of the cases, INTERSECT key results will follow the Free and Open Source business model. An exception is the IM2D platform: for it an hybrid business model will be adopted in order to combine open source codes (QE, SIESTA, AiiDA, SimPhoNy) freely available under GPL license and reusable for any potential use, used by the academic research groups, with the Applied Materials proprietary software Ginestra™ distributed under commercial license.

7. Marketing Plan

7.1 Revenue & cost analysis

7.1.1 Revenue stream

As described in the exploitation model section in D.4.8 “Innovation management assessment and revision” [see also 16], a few possible revenue models have been considered for INTERSECT results:

- Commercial / proprietary business model;
- Free and Open Source model;
- Mixed Open Source and commercial business model;
- Services and consulting;
- Government funding.

In the Innovation exploitation phase, we have identified the appropriate business models and have elaborated the business model canvas earlier presented in this document (see sect. 3.1 to 3.7).

7.1.2 Cost impact

In any business model it is very important to analyze the involved costs in order to prepare a reliable plan. Surely, as a first voice, the labor cost significantly affects the budget of all the key exploitable results, whatever the kind of model might be chosen. Then, if the cloud-based model is chosen, cloud infrastructure investments are needed especially to preserve the protection of data that in most cases industries are not prone to disclose. Similarly, for an n-premises distribution model, costs are mainly related to the product release and to the IT support for installation. Hybrid distribution is affected by both. Using a proprietary license commercial model requires an additional cost for professional data security and support services.
In case of mixed models like IM2D the goal is to balance the costs in order to be able to propose a competitive price for the whole solution. The consulting business model is the simplest one, since all the cost of personnel and infrastructure are charged to the end user.

7.2 Distribution strategies

There are different strategies on how to deliver software to end users:

- Making a product installable on the customer's premises;
- Making a product available online via cloud hosting (i.e., the 'software-as-a-service' distribution);
- Combining these two strategies (the 'hybrid' distribution strategy).

7.2.1 On-premises software distribution approach

The on-premises distribution approach entails a software product being installed to run within the end user's in-house infrastructure, be that a single computer or a local server. The traditional distribution approach has been used for many years by companies such as SAP, Oracle, and Microsoft. Within INTERSECT, Ginestra^{TM} adopts this distribution approach.

Pros of traditional on-premises software distribution approach	Cons of traditional on-premises distribution approach
On-premises deployment allows the customization of the product, and its alignment with client' needs.	Implementation of a new on-premises environment requires a lot of time.
It allows simple integration with the end user's systems over the intranet.	The end user must have its own IT support staff and in-house server hardware if you provide corporate-level software.
All infrastructural expenses are covered by the end user.	If a product is distributed via a license model like Ginestra^{TM}, the end users can be hesitant

	about making a large, upfront investment in a license considering the risks.
	If on-premises software was customized, upgrading it becomes increasingly more complicated.

Table 18. Pros and cons of traditional on-premises software distribution approach.

7.2.1 Cloud-based software distribution approach

The main characteristic of the cloud-based distribution approach is that the software runs at a hosting provider server or in the cloud service. For instance, **software as a service** (SaaS) is a cloud-based distribution approach in which a provider hosts its applications and makes them available to customers via the Internet. According to the SaaS method, businesses and individuals do not need to install applications on their own computers or own data centers. They can access the software using a Web browser or a mobile device. Amazon Web Services, Dropbox, and Netflix are well known examples of this kind of approach. SaaS is typically delivered via a term-based subscription. AiiDA, QE and SIESTA follow this distribution approach.

Pros of the cloud-based distribution approach	**Cons of the cloud-based distribution approach**
Cloud products and services have faster implementation timeframes for end users.	There may be compatibility issues between cloud solutions and integration with existing on-premise enterprise applications that clients may already have.
Users will be able to access products and information remotely from anywhere at any time, an Internet connection given.	Customers are fully responsible for service outages that may occur. Setting up reliable infrastructure is required.
The SaaS approach doesn't require any initial setup costs from users. The customers just need to subscribe and log into their account to get full access to the app and its updates.	
The SaaS approach gives the opportunity to provide the same software version for all customers. This means that a single version	

needs to be maintained, upgraded, debugged, and provided storage support for.	
The main revenue stream of the cloud distribution approach is subscriptions, then it is possible to receive revenue as long as the client uses the software, on an ongoing basis.	

Table 19. Pros and cons of cloud-based distribution approach.

7.2.3 Hybrid software distribution approach

Some software companies opt for a hybrid distribution approach. Hybrid in this case is the approach that combines a SaaS solution with an on-premise software application. So, a cloud-driven technology complements an on-premise one. IM2D will follow this kind of approach.

Pros of hybrid software distribution	Cons of hybrid software distribution
It provides the end user with the flexibility to move information between on-premises and cloud-based solutions based on their needs. E.g., semiconductor industries are more IP sensitive than Academia. Cloud-based industries can present a high-risk of IP data leakage.	On-premise has limited customization opportunities compared to that of a pure cloud version.
Users can take advantage of tight integration with existing corporate systems and reduce the implementation and switching costs.	If customized, the software update might become a critical engineering challenge.
Request a low computational requirement. It can run on a standard laptop allowing work from anywhere.	If software is accessible both from a web interface and an on-premise interface, the amount of front-end development tasks significantly increases.

Table 20. Pros and cons of hybrid software distribution.

7.3 Source code licensing

In this chapter we explain how Software companies can create **proprietary or open source** software.

7.3.1 Proprietary software

As the Ginestra^{TM} software, **a proprietary software** does not let the user access, change, or reuse the copyrighted source code. Even if a program is free for use, it may have proprietary pieces of code that users and third parties cannot change. In this case, code written in a high-level language is assembled in a machine language, which is executable by a machine but unreadable by a human. Most companies make their software products proprietary to protect it from copying, changing, or emulating.

Pros of creating proprietary software	Cons of of creating proprietary software
Reliable: users are certain that the product will work properly due to a single source for support, bug fixes, security fixes, and regular upgrades.	As described in the "pros" section, the owner of proprietary software is responsible for all updates, customization (if any), and maintenance. A limited engineering capacity may slow down feature developments compared to competing providers.
Exploitable: Software is protected by copyright and can be monetized.	The code-owning organization is the only responsible for finding and fixing code vulnerabilities. So, closed-code software is more likely to be vulnerable to malware and attacks than open-source code where possible exploits can be better detected as a community effort.

Table 21. Pros and cons of creating proprietary software.

7.3.2 Open source software

Open source software means that users get free software and access to source code. AiiDA, QE, SIESTA, and SimPhoNy are MIT and GPL Open Source software. In addition, most of INTERSECT results are expected to be Open Source.

Pros of creating open-source software	Cons of of creating open-source software
OSS is a great opportunity to present the innovative features and technical capabilities of the product to attract more users.	The quality of OSS is sometimes less accurate than the proprietary version.
End users can customize a product for their needs.	Big companies do not allow or are skeptical to use OSS in their daily operations.
OSS is a good way to improve brand recognition among technology companies.	Creating open source products requires finding additional revenue streams.
OSS has less chances of having vulnerabilities as they can be detected by a community.	

Table 22. Pros and cons of creating open-source software.

7.4 Communication plan

The communication plan plays a crucial role in informing the possible stakeholders on the availability of the IM2D device and its features, and helping mitigate adoption barriers, e.g., the industry's skepticism. As mentioned earlier, the semiconductor companies are mainly using semiconductor software solutions currently available on the market: their skepticism is related to either the technical differentiation of the software results and the reliability and quality of the products. These aspects could represent a barrier for the IM2D penetration into a market dominated by few big corporations.

This barrier can be reduced by dedicated actions, that may be, among others:

- **The validation of the IM2D platform by early adopters:** AMAT, FMC, and IMEC are the internal early adopters. Using an industrial point of view, they will contribute for the quality assessment of the platform, facilitating an industrial qualification.
- **The partnership with worldwide research centers:** expanding the network of key partnerships and collaborations including worldwide-ranked research centers is crucial; all the academia partners are part of the EMMC community and other relevant scientific foundations (OPTIMADE, MAX,…). Two members of the INTERSECT team (FRA, IMEC) are also partners of the European Semiconductor Industry Association (ESIA), whose mission is the promotion of the EU semiconductor industry to ensure a sustainable business environment and foster its global competitiveness.
- **Efficient dissemination activities for promoting INTERSECT results** (described in details in the D4.4 and update at the end of the project in D4.9):

- **Website:** in the INTERSECT website https://intersect-project.eu/industry/ an "industry" page has been developed to showcase the IM2D platform; synthetic tabs about the other key exploitable results are going to be realized.
- **Newsletter**: the INTERSECT newsletter has been designed to update the end user on project and IM2D progress. The next issues will be focused on the latest project advancements, including the key exploitable results, and the upcoming workshop.
- **Social media**: Twitter, LinkedIn, and Instagram channels are actively used to promote project results.
- **Papers and Conferences**: to engage the scientific and industrial community the consortium has a wide dissemination activity. Some papers have been published in journals with high H-index factors, while presentations and posters have been given to worldwide-relevant conferences like IEDM, NN21.
- **INTERSECT workshop**: a specific workshop will be held at the end of the year (Nov. 2021), open to both academic scientists and industrial stakeholders and a showcase of IM2D will be officially presented. Invited audience include people from R&D labs, SMEs, and large companies (see website).
- **Trade fairs/Research To Business events:** participation to industry-related events, where the IM2D, and possibly key features as well, can be presented to possible stakeholders.
- **Targeted mailing/announcements to key partners/selected segments**: they will be defined and sent in conjunction with the project press release related to the IM2D finalization, and the synthetic tabs.

8. Conclusions

In this deliverable the INTERSECT Business plan has been assessed and revised from the D4.3 version (M19). Starting from the D4.8 exploitation phase results, we elaborate the business models for each key exploitable result. According to the project goals, a business model canvas, an extensive market research, and a SWOT analysis have been deployed to analyze and assess the positioning of the "pre-competitive" solutions. In the marketing plan we described the revenue & cost stream, the distribution channels, the type of source code licenses and the communication plan.

This analysis indicates a promising and fruitful market opportunity and sustainability of the key exploitable INTERSECT products, especially the IM2D box that can penetrate and have a unique position in the Atomistic-TCAD segment for the design of advanced electronic devices. However, since commercialization goes beyond the aim of this project, some critical aspects (such as the definition of the legal entities, the marketing strategy or the plan for the return on investment) have not been investigated in the present document. This does not limit the validity/quality of the project results or modify the interest of industrial stakeholders on the IM2D product.

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ACRONYMS

AI - Artificial Intelligence

CAD - Computer-Aided Design

CAGR - Compounded Average Growth Rate

D2M - Device-to-Material

DFM - Design for Manufacturability

DFT - Density-Functional Theory

DoA – Description of the Action

EDA - Electronic Design Automation

EMMC - European Materials Modelling Council

EMMO - European Material Modelling Ontology

ESIA - European Semiconductor Industry Association

FOSS - Free and Open Source Software

GPL - General Public License

GUI - Graphical User Interface

IC - Integrated Circuit

IDM - Integrated Device Manufacturer

IM2D - Interoperable Material-To-Device Simulation Box

IP - Intellectual Property

IoT - Internet of Things

LGPL - Lesser GPL

M2D - Material-to-Device

MCM - MultiChip Modules

NEB - Nudget Elastic Band

OSS - Open Source Software

PCB - Printed-Circuit Board

PCM - Phase-Change Memory

QE - Quantum ESPRESSO

SaaS - Software as a Service

SAM - Served Addressable Market

sHub - Simulation Hub

SIP - Semiconductor IP

TAM - Total Addressable Market

TCAD - Technology-Computer-Aided Design