PCIC ENERGY 2024 Rotterdam
How digital enables Carbon Footprint implementation?

Paper No. PCIC energy EUR24_16

Guilhem Jean
2B1st Consulting
943 route des Pecles,
74400 Chamonix
France

Abstract - In our world of energy, driving toward more and more sustainability, the carbon footprint is becoming the KPIs to measure the efforts made by operators to fight climate change.

As the rather simple concept of accounting the CO2 equivalent emissions of a company activities, Carbon footprint complexifies on its execution to the extent of appearing impossible.

In this paper we will explain how digital technologies can support / enable the implementation of carbon footprint.
The first part of the paper will focus on the data acquisition, aggregation and analysis.
Then, the paper will focus on the accounting and transparency of the carbon footprint.
Last part of the paper will be dedicated to the reporting and modeling of carbon footprint in the target of reduction.

I. INTRODUCTION

On the last 10 years, operators have spent half of their resources on R&D on digital technologies to revolutionize their operations.

By nature, the complexity of energy projects and processes offers great use cases for digital technologies to solve pain point. But today, the energy industry may face its biggest challenge by its impact on climate change. Oil & Gas and Petrochem projects are high contributors to green house gases emissions.

Aware of this problematic, Operators are reinventing themselves to become energy companies and take an active part in Energy Transition.

While doing so, one of the main pressures received by operators is to reduce their emissions of green house gases. Producing clean energy is great but clearly not enough to fight climate change and the attention given to the carbon footprint of those giant energy companies is raising fast.

The pressure may come from their shareholders, regulations, the COP 28 or to their internal personnel; each company needs to take action regarding its carbon footprint. This measurement of Carbon footprint is often part of broader sustainability initiatives and can be used to set emission reduction targets and demonstrate corporate responsibility.

In this paper we will explain the basics of Carbon footprint as well as why is digital technologies an enabler of those advancements.

II. CARBON FOOTPRINT DEFINITION AND SCOPE

The carbon footprint of a company refers to the amount of greenhouse gases, specifically CO2 and other equivalent gases, that are directly or indirectly emitted by the company's activities.
It measures the environmental impact of the company's operations and provides insight into its contribution to climate change.

The gases responsible for the greenhouse effect are the following with their Global Warming Potential and concentration in the atmosphere (approximate values for reference) :

TABLE I
Greenhouse Gases

Greenhouse Gas	GWP (100-year)	Atmospheric Concentration (Approximate)
Carbon Dioxide (CO2)	1	0.0415% (415 ppm)
Methane (CH4)	25	0.00018% (1.8 ppm)
Nitrous Oxide (N2O)	298	0.00033% (3.3 ppm)
Sulfur hexafluoride (SF6)	23,500	Parts per trillion
Water Vapor (H2O)	Not commonly quantified due to its short atmospheric residence time	2%
Ozone (O3)		
Chlorofluorocarbons (CFCs)	7000	Varies (typically measured in parts per trillion)
Hydrofluorocarbons (HFCs)	4000	
Perfluorocarbons (PFCs)	10,000	

The carbon footprint takes into account various factors, including:

Direct Emissions (Scope 1): Those emissions are directly produced from sources that are owned or controlled by the company. For example, emissions from combustion of fossil fuels in company-owned vehicles or facilities.

Indirect Emissions from Energy Use (Scope 2): Those emissions are from the generation of purchased electricity, heat, or steam consumed by the company. It reflects the environmental impact associated with the company's energy consumption.

Other Indirect Emissions (Scope 3): These are emissions from sources not owned or directly controlled by the company but are related to its activities. This can include emissions from the supply chain, transportation of goods, and employee commuting.

By quantifying and understanding its carbon footprint, operators can identify the opportunities to reduce their emissions, or improve their energy efficiency. But the carbon footprint also differs depending on the project cycle. In our industry, it is important to make the difference between the carbon footprint of the construction of the project, and later the carbon footprint associated with the operations of the project.

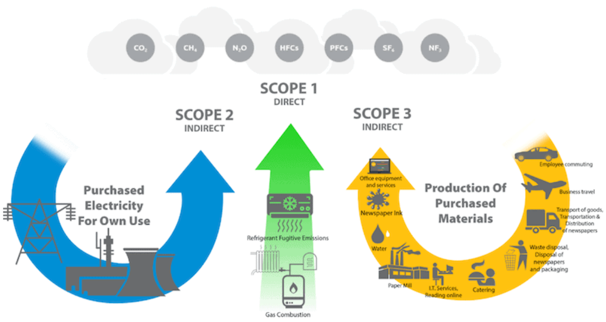

Figure 1 : Scope 1, 2 and 3 of the Carbon Footprint

The **carbon footprint during the construction** phase of a project integrates the greenhouse gas emissions generated throughout the process of creating the infrastructure. This phase involves a series of activities that contribute to emissions, including the production of construction materials and equipment, transportation of those to the construction site, on-site construction activities, and the utilization of heavy machinery. Emissions arise from the carbon used to produce material and equipment, the energy consumed during construction, and the various construction processes. Despite being a short phase compared to the overall lifespan of the operation, the construction phase plays a crucial role in determining the initial environmental impact of the project.

In contrast, the **carbon footprint during the operation** phase focus on the emissions generated during the regular functioning of the infrastructure. This phase involves ongoing activities such as heating, cooling, lighting, and the operation of electrical systems. Not to be forgotten is the leakage of carbon material, especially important in LNG applications, as well as venting or flaming procedures. All of which contribute to energy consumption and associated emissions. The carbon footprint during operations also includes emissions from maintenance activities and any other processes tied to the building's energy use throughout its operational life. Notably, the operational phase spans the majority of the structure's lifespan, and its impact on the environment is continuous as long as the building remains in use.

The key distinctions between the carbon footprints during construction and operation lie in the timing of emissions, the activities driving emissions, and the relative duration of each phase. Construction-phase emissions are concentrated during the shorter duration of building creation and are primarily linked to material production and construction activities. Operational-phase emissions, on the other hand, continue over the longer operational lifespan of the asset and are mainly associated with the ongoing energy consumption required for day-to-day activities. Both phases are critical considerations in assessing and mitigating the overall environmental impact of a project.

III. CARBON FOOTPRINT CALCULATION COMPLEXITY

While being a quite clear idea the calculation of the carbon footprint of a company remains complex exercise due to different factor of the environment.

The first issue is usually to select the framework adapted to your situation. And to calculate the carbon footprint of a company you would aspire to follow a recognized standard or guideline to ensure consistency, transparency, and accuracy. Here below are some of the key norms and standards commonly used for calculating and reporting corporate carbon footprints:

1. Greenhouse Gas Protocol (GHG Protocol)
2. ISO 14064-1
3. ISO 14064-3
4. Carbon Trust Standard:
5. Science-Based Targets Initiative (SBTi)
6. CDP (formerly Carbon Disclosure Project)
7. EU Emission Trading Scheme (EU ETS)

By the sole existence of different standards for the same application, a lot of entropy and complexity may exist to select the framework most likely to become the international norm.

The second issue, which is especially true in the energy industry, is the complexity of the supply chain. Calculating the carbon footprint of an oil and gas company involves a comprehensive assessment of greenhouse gas (GHG) emissions associated with its operations (Scope 1), indirect emissions from purchased energy (Scope 2), and other indirect emissions from the value chain (Scope 3). While Scope 1 & 2 can be evaluated quite quickly due to their internal grip, Scope 3 becomes more complex.
The usual project of Oil & gas or Petrochem involves between 100 to 200 companies; form the engineerings to the OEMs and the sub sub sub sub sub sub sub suppliers.
On top of the number of suppliers, the usual architecture of a project also involves a vast number of countries.
And for operators responsible for their carbon footprint, it becomes quite a communication exercise to acquire the carbon footprint of the bolt used to seal two pipes together in the cooling system of the electricity supply.

The third issue in the calculation itself. Because the calculation involves identifying all emission sources within the company's operational boundaries. Then gather relevant data on energy consumption and fuel usage, convert emissions to CO2 equivalent using global warming potential (GWP) factors, sum up emissions from all three scopes to obtain the total carbon footprint, and finally, prepare a detailed report with methodology, data sources, and results.

Those three issues often result in the demotivation of actors in calculating their carbon footprint or in partial calculations of the carbon footprint. For both cases, the result is clearly not enough and is called to change in the next few years as European, but not only, laws is making a requirements for any medium and large size company to calculate and publish its carbon footprint.
Thus, it is interesting to see how digital technologies have been used in the recent months to helps company solve the many pain points around their carbon calculations.

IV. FROM DATA CAPTURE TO AGGREGATION

As explained on the previous part, one of the key factor behind the complexity and failure to calculate the carbon footprint of a company is around the data. How to access the right information and how to vehicle properly an high volume of variables.
In this sense, the usual answer is to put in place project by project an IT infrastructure responding to the sweet name digital twin “As built” project life cycle to.

A. Data Collection and Monitoring:
Digital technologies have revolutionized the way organizations collect and monitor data relevant to their carbon footprint. Internet of Things (IoT) devices and sensors, strategically placed in operational process, provide real-time insights into energy consumption, emissions, and various environmental parameters. These sensors offer a granular sampling of the organization's ecological impact. It allows a continuous monitoring and a precise data collection. Additionally, smart sensors, another digital innovation, enable real-time tracking of energy usage, covering electricity, gas, oil, and water consumption. This volume of data serves as a foundation for accurate carbon footprint calculations. To share a figure, the average refinery would collect 1 million data per minute in order to completely cover its assets and process.

B. Data Management and Analytics:
The advance of cloud computing has transformed the landscape of data management for carbon footprint calculations. The numerous cloud platforms offer secure and scalable storage solutions, facilitating the efficient organization and retrieval of large datasets related to emissions. This digital infrastructure empowers operators to employ advanced analytics tools for in-depth analysis. Big data, a key component of analysis, enables the identification of patterns and trends in historical and real-time emission data. Machine learning algorithms or Artificial Intelligence solutions, integrated into analytics tools, provide predictive insights, to assist organizations in anticipating and addressing future emission trends.

C. Carbon Accounting Software:
Dedicated carbon accounting softwares have emerged recently as a critical tool for companies committed to reducing their carbon footprint. These specialized softwares follow one established standards, like the Greenhouse Gas Protocol, and streamline the process of data collection, calculation, and reporting. With features designed for accuracy and compliance to environmental accounting principles, these softwares often integrate seamlessly with other enterprise systems, such as Enterprise Resource Planning (ERP) solutions. This integration ensures that emissions data is not isolated but connected to broader organizational data flow, providing a comprehensive view of the carbon footprint and a guarantee of veracity of the data.

D. Legal compliance
The significance of digital systems, particularly in the context of regulatory compliance, is vital for managing and mitigating carbon footprints. These digital systems play a crucial role in assisting organizations in adhering to stringent environmental regulations. By leveraging digital technologies, organizations can automate the complex process of data collection, analysis, and reporting, ensuring that their emissions data aligns seamlessly with regulatory requirements. This not only streamlines the reporting process but also minimizes the risk of errors and inaccuracies, boosting transparency and accountability. Moreover, digital systems enable real-time monitoring, allowing organizations to promptly identify and address any deviations from compliance standards. The ability to stay updated according to evolving regulatory frameworks has become a must to meet environmental obligations, minimize legal risks, and contribute to a more sustainable approach to business operations.

V. FOR TRANSPARENCY AND VALUE CREATION

Once you managed to calculate your carbon footprint, the job is not completely done. A typical major International Oil Company carbon footprint can range from 300 to 500 million tons of CO2 equivalent per year, as per their calculations. On the other side, some green environmentalist associations estimated the same carbon footprint to be in the range of 700 to 900 million tons minimum.
This difference is clearly abyssal and raise some concern from shareholders into the validity of calculations made by companies. And to this matter, there is no alternative other than having a full transparency on the calculations, as well as a robust method for its accounting. To this extent it is important to have a collaboration between all the stakeholders of the carbon footprint internal or external of the companies in order to avoid mis conduct or accusations of green washing for example.

A. Blockchain Technology:
Blockchain technology offers innovative solutions for enhancing transparency and traceability in carbon footprint management. In supply chains as complex as they can be in Oil & gas projects, blockchain enables organizations to create a transparent and immutable ledger, allowing for the traceability of equipment and raw materials. This is particularly impactful for understanding and managing Scope 3 emissions, as companies or scrutators can trace the entire life cycle of products. Additionally, blockchain can be leveraged for the tokenization of carbon credits.

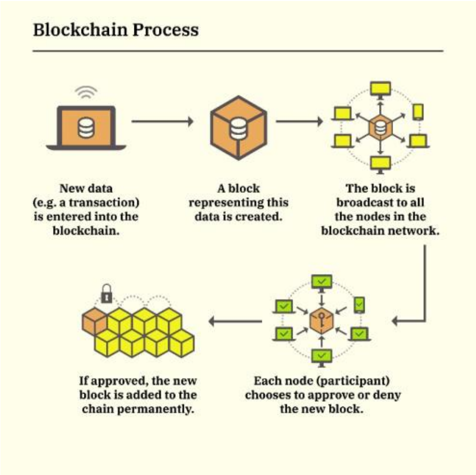

Figure 2 : How does a blockchain works

By creating digital tokens representing carbon credits, organizations can trade these assets securely and transparently on blockchain platforms, contributing to more efficient and trustworthy carbon offset projects.

Figure 3 : Certification of carbon footprint by blockchain

B. Digital Collaboration:
Digital collaboration tools have become essential for engaging various stakeholders and departments in the process of carbon footprint management. These platforms facilitate seamless communication and data sharing among different parts involved in sustainability initiatives (auditors, associations, government, shareholders, etc). Through digital collaboration, organizations can ensure that all relevant departments contribute data, insights, and feedback, resulting in a more comprehensive and accurate assessment of the carbon footprint. The collaborative nature of these tools promotes a shared understanding of sustainability goals and encourages a collective effort toward emissions reduction.

C. Digital Twin:
Digital twins, virtual replicas of physical assets and processes, are increasingly used for simulating and modeling various scenarios related to emissions reduction. Organizations can create digital twins of their processes as well as operations to simulate the impact of different strategies/designs on their carbon footprint. This allows for a proactive approach to emissions management, enabling organizations to assess the feasibility and effectiveness of different initiatives before implementation. Digital twins contribute to informed decision-making by providing a virtual environment for testing and refining strategies to achieve emissions reduction targets.

D. Remote sensing and Satellite
The integration of remote sensing and satellite technology is great for assessing carbon footprints due to its unique advantages in providing comprehensive, timely, and objective data. Satellites also offer a global perspective, capturing information over vast areas, making it invaluable for monitoring the leakage of gas product on offshore or onshore plants in remote areas. The technology's ability to provide consistent, unbiased data enhances the reliability of information used in carbon footprint assessments by operators.

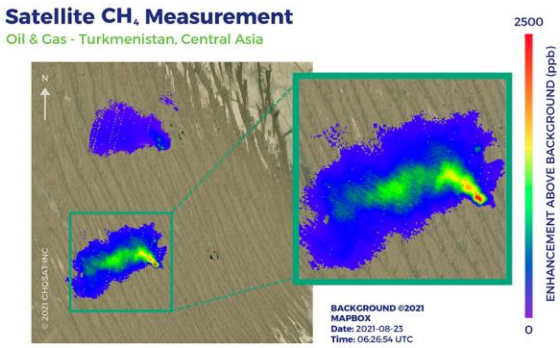

Figure 4 : Methane leakage detected by Satellite

Moreover, remote sensing helps in identifying carbon hotspots, areas with significant emissions or land-use alterations, guiding targeted actions for the mitigation of those emissions. By detecting changes in carbon emissions of operations, operators can act faster to tackle their failure. Integrating this data into carbon accounting models facilitates accurate estimates of carbon stocks, emissions, and removals, thereby enhancing the precision of carbon footprint assessments and informing policies for sustainable practices.

VI. SOCIAL RESPONSIBILITY

Beyond the carbon footprint itself, this topic has raised many questions about the activities of the major oil companies and their benefit to society. While delivering cheap and secure energy has been the main request for a long time, it seems to fell short in this new paradigm of climate change.
People no wants oil majors to become energy companies and lead the energy transition while fighting climate change. The new requirements for energy are : be cheap, be available, be sovereign, be clean. This complex equation is almost impossible to solve with a simple answer but it has least provide a direction for the strategy of the operators that still want to exist in the next decades.

A. Carbon Credits:
The application of blockchain technology in the realm of carbon credits extends to tokenization and secure trading. By digitizing carbon credits on a blockchain or other mean, operators can enhance the transparency and integrity of their carbon offset projects. Blockchain provides an immutable record of transactions, reducing the risk of fraud accusation and ensuring the credibility of carbon credit transactions. The tokenization of carbon credits on a blockchain platform opens up new possibilities for efficient and trustworthy carbon offset markets, encouraging broader participation in sustainability efforts.

B. Mobile Apps and Employee Engagement:

Mobile applications play a pivotal role in tracking and engaging employees in sustainable practices that contribute to emissions reduction. These apps can monitor employee travel, commuting patterns, and other activities that impact the organization's carbon footprint. By integrating employee data into carbon footprint calculations, organizations gain a better understanding of their carbon impact. Beyond data collection, mobile apps also serve as tools for engaging employees in sustainability initiatives. Organizations can use those apps to educate, motivate, and recognize employees for adopting eco-friendly practices, fostering a culture of environmental responsibility within the workforce.

C. Energy Management System

Energy Management Systems (EMS) play a pivotal role in the effort to manage and mitigate carbon footprints. By focusing on optimizing energy usage within plant and processes, EMS contributes significantly to the reduction of carbon emissions. These systems provide a sophisticated framework for organizations to monitor, control, and enhance the efficiency of their energy consumption. Through real-time data analysis and advanced automation, EMS identifies opportunities to minimize energy waste, streamline operations, and implement demand response strategies. By maximizing energy efficiency, organizations can lower their usage of fossil fuels and decrease overall energy-related emissions. The importance of Energy Management Systems lies in their ability to enhance operational cost-effectiveness.

VII. CARBON FOOTPRINT REDUCTION IN APPLICATIONS

A. Venting and flaring

Digital technology stands as a transformative force in the reduction of carbon emissions associated with venting and flaring operations. Real-time monitoring, facilitated by digital sensors and analytics, provides immediate insights into emissions levels, enabling timely interventions. Automated detection algorithms identify abnormal patterns, allowing for quick responses to deviations from standard operations. The ability to remotely control and optimize venting and flaring processes enhances efficiency, while predictive maintenance tools can prevent equipment issues that might contribute to emissions. Integration with process simulation and data analytics platforms empowers operators to make informed, environmentally conscious decisions, optimizing combustion processes and exploring alternative strategies. Moreover, digital systems streamline regulatory compliance by automating reporting, ensuring adherence to environmental standards.

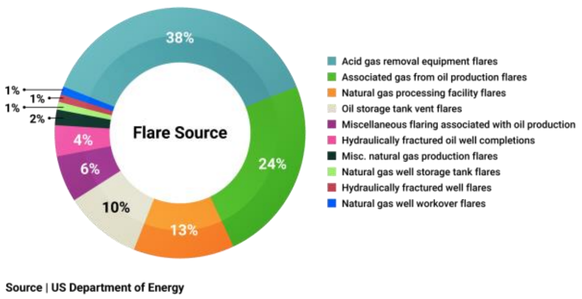

Figure 5 : Gas flaring by sources

The continuous feedback loops established through data analysis foster a culture of ongoing improvement, driving sustained efforts to cut emissions in venting and flaring activities. Overall, the utilization of digital technology presents a comprehensive and dynamic approach to minimize the environmental impact of these operations.

B. Leakage

Digital technology emerges as a pivotal force in curbing carbon emissions due to oil and gas operations' leakages. Employing advanced monitoring systems, digital sensors, and drones facilitates swift detection of leaks, minimizing the duration and environmental impact. The integration of IoT devices and smart sensors along pipelines provides real-time data for proactive leak prevention and rapid response. Data analytics and predictive modeling identify patterns to predict leaks, while remote valve control enables immediate isolation of affected areas. Blockchain enhances traceability, aiding in the swift identification of leak sources. Digital twin simulations optimize maintenance and preemptively address vulnerabilities. Continuous Emission Monitoring Systems (CEMS) ensure compliance and enable real-time measurement of emissions.

Autonomous inspection vehicles and collaborative platforms further bolster the industry's collective capability to detect, respond to, and prevent leaks, fostering a more sustainable and environmentally responsible approach to oil and gas operations.

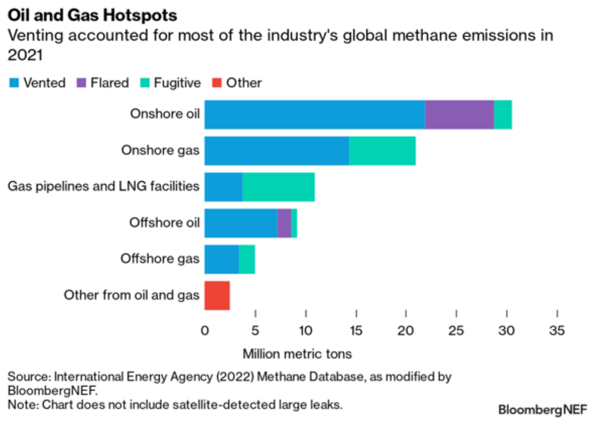

Figure 6 : Flared compared to leakage carbon footprint

C. Energy efficiency

Digital technology emerges as a critical tool in the pursuit of heightened energy efficiency and diminished carbon emissions across oil and gas operations. Employing real-time monitoring systems and sensors allows operators to finely tune energy consumption, identifying inefficiencies throughout the production process. Predictive analytics preempts equipment failures, reducing downtime and optimizing energy utilization. Automation and robotics streamline operations, reduce human errors and increasing overall efficiency. IoT-enabled asset management provides remote oversight, enabling timely interventions and energy conservation. Digital twins, through simulation and optimization, pinpoint energy-saving opportunities and inform strategic changes. The integration of energy-efficient technologies, such as advanced control systems, further diminishes consumption. Data-driven decision-making, facilitated by analytics platforms, guides strategies for energy efficiency improvements. Remote operations and condition monitoring minimize travel-related emissions, while blockchain technology ensures transparent transactions and fosters accountable practices.

D. Carbon emissions compliance

Digital also plays a pivotal role in enabling the carbon emission monitoring and reporting to comply with environmental regulations in various regions like Europe or USA. Connected sensors and smart metering provide real-time data to ensure an accurate monitoring. Blockchain should ensure secure and transparent carbon accounting which is crucial for the regulatory transparency.

AI algorithms will be most likely be able to predict future emissions, aiding proactive compliance strategies. Cloud-based platforms will simplify the generation of centralized and accessible reporting. Ultimately, these digital tools contribute to efficient, transparent, and compliant carbon emission monitoring and reporting, helping organizations adhere to environmental laws across different regions.

VIII. NOMENCLATURE

GWP Global Warming Potential
EMS Energy Management System
CEMS Continuous Emission Monitoring Systems

IX. CONCLUSION

In conclusion, this paper has underscored the transformative role of digital technologies in revolutionizing how we approach carbon footprint implementation in the energy industry.

The integration of advanced digital tools, from real-time monitoring and predictive analytics to remote operations and collaborative platforms, has opened an era of unprecedented efficiency and sustainability. These technologies not only provide real-time insights into energy consumption and emissions but also empower proactive decision-making for optimizing emissions. The ability to simulate, analyze, and optimize operations through digital twins fosters continuous improvement, while blockchain and IoT enhance transparency and traceability.

As we navigate the complexities of mitigating carbon emissions, it is evident that digital technology serves as a enabler to support the industry to embrace innovative solutions and transition toward a more sustainable and environmentally conscious future.

The journey towards a low-carbon energy landscape is still challenged but thanks to the pioneering contributions of digital advancements, our pursuit of a greener and more resilient energy sector is achievable.

X. ACKNOWLEDGEMENTS

I extend our sincere gratitude to the esteemed experts of the Greenhouse Gas Protocol for their invaluable contributions to the development and refinement of essential tools and standards for measuring and managing greenhouse gas emissions.

Their dedication and expertise have played a pivotal role in shaping the landscape of sustainability reporting, carbon accounting, and emission reduction strategies. Through their tireless efforts, these experts have significantly advanced the understanding and implementation of best practices in quantifying and mitigating greenhouse gas emissions, paving the way for a more sustainable and resilient future. I deeply appreciate their commitment to environmental stewardship and their unwavering support in catalyzing positive change across industries globally.

XI. VITA

Jean Guilhem graduated from the engineering school Supélec Paris with a specialization in Electro-communication. After several experiences in Siemens Oil&Gas and Air Liquide Large Industry working on digital topics, he received a MBA degree from the SDA Bocconi in Milan. Joining 2b1st Consulting in 2018, he is now the CEO of the company pursuing the heritage of expertise in energy and digitalization.
guilhemjean@2b1stconsulting.com