Future battery technologies for transport applications

March 2017

MOZEES
Mobility Zero Emission Energy Systems

FME

Who is Saft today?

GROUP PROFILE

~100 years of history

4100+ people

3000+ customers

Leadership position on 75-80% of revenue base

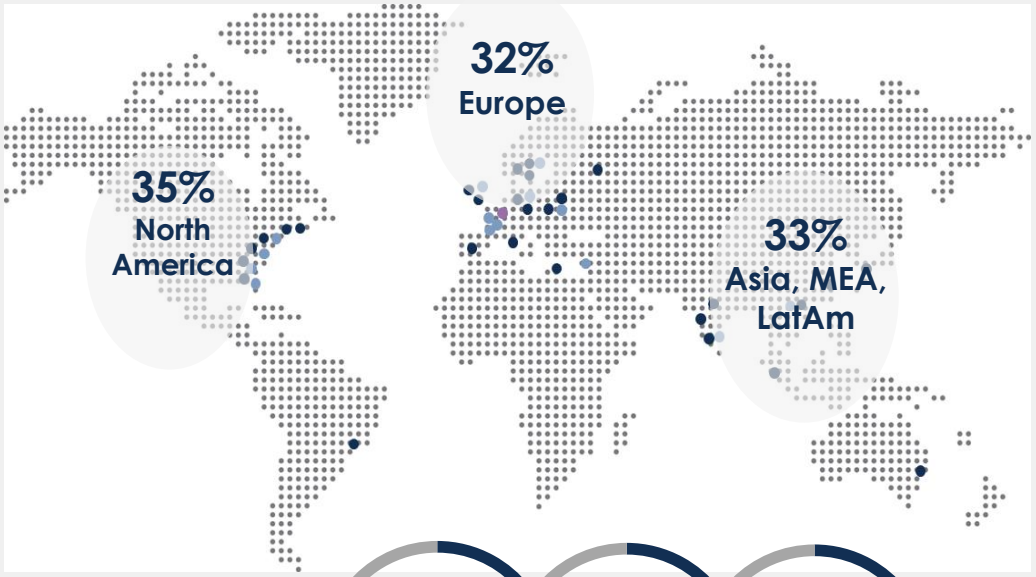
9% invested in **R&D** with **3** main technologies

€738m revenue FY 2016

TOTAL COMMITTED TO BETTER ENERGY

4th largest oil&gaz company
100,000 employees
130 countries

INTERNATIONAL PRESENCE



14 manufacturing sites

19 countries

31 sales offices

MOZEES Mobility Zero Emission Energy Systems

saft

Saft Businesses

Civil Electronics

- Smart metering
- Electronic Toll Collection (ETC)
- E-call
- Asset tracking
- Internet of Things (IoT)
- Medical devices
- Portable military
- Oil drilling

Industrial Standby

- Emergency back-up power, starting power and cycling applications in the oil and gas industry
- Power generation and distribution
- Railway signaling systems

Civil Aviation

- Backup power and emergency systems
- Engine and turbine starting

Ground Transport[1]

- Backup power for lighting, air-conditioning & on-board [illegible] safety applications (emergency braking & door opening systems)
- Electrification of industrial vehicles

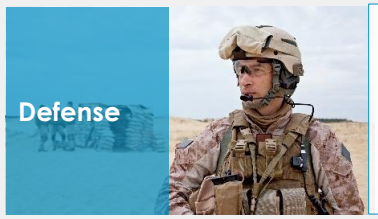
Telecom & Grid

- Backup power for the telecommunications industry
- Storage solutions for installation & renewable generation plants, micro- & distribution grids, and commercial or industrial end user sites

Transport & Telecommunication & Grid

Space

- Communications, scientific and military satellites
- Satellite launchers
- Space vehicles



Defense

- [illegible] camps
- Weapon systems & torpedoes
- Military aircraft
- Hybrid armored vehicles

Marine

- Work boats
- Ferries
- Cruise liners & luxury yachts
- Cargo & offshore vessels

Space & Defence

Saft Corporate Research

Saft Corporate Research perimter

From the atomic to the system scale

- **Active material** is only one piece of the entire puzzle, **success** depends on all **cell** and **battery** components
- **Battery manufacturer expertise :** how to minimize the loses at each scale change ?

- **New materials, chemistries**
- **New process**
- **Innovative materials for systems**
- **Models and algorithms**

Materials design	Electrode design	Cell design	Battery design
Active materials Structure, Composition Coatings **Non active additives** **Electrolyte**	**e- conductivity** **Ionic conductivity** **Porosity, tortuosity** **Wettability** **Binders, foils**	**Loading** **Cell balance** **Electrolyte** **Connections** **Can**	**Mechanics** **Bus bar** **Thermal** **Electronics** **BMS, algorithms**

Scope

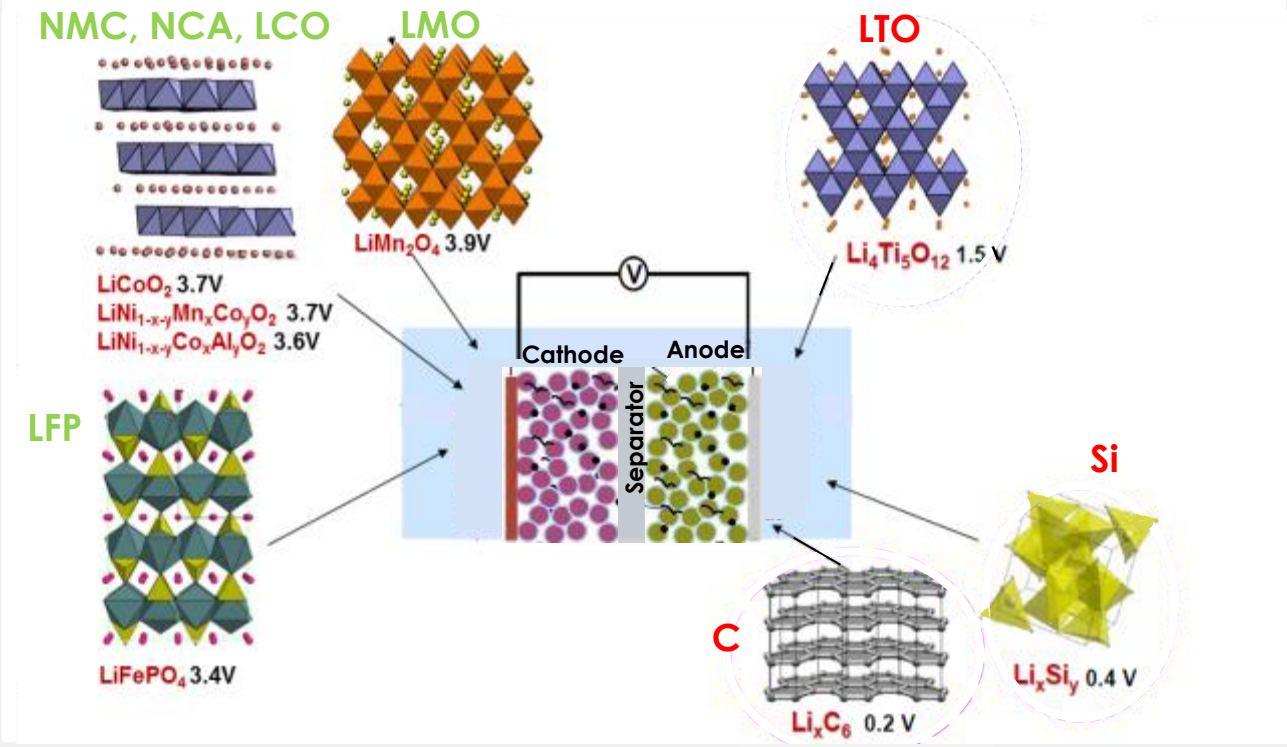
Multi technologies portfolio

- Support of traditional **Alkaline** (NiCd, NiMH), **Primary Lithium systems** ($LiSOCl_2$, $LiSO_2$, $LiMnO_2$, $LiCF_x$)
- Focus on **Li-ion** chemistries (NMC, NCA, LFP, LTO)

Today's Li-ion technologies

After many decades of screening, **very few elected commercial cathode and anode materials**

- **Each Li-ion sub-technologies with its own domain of excellence today and in the future**



What is the next technology beyond Li-ion?

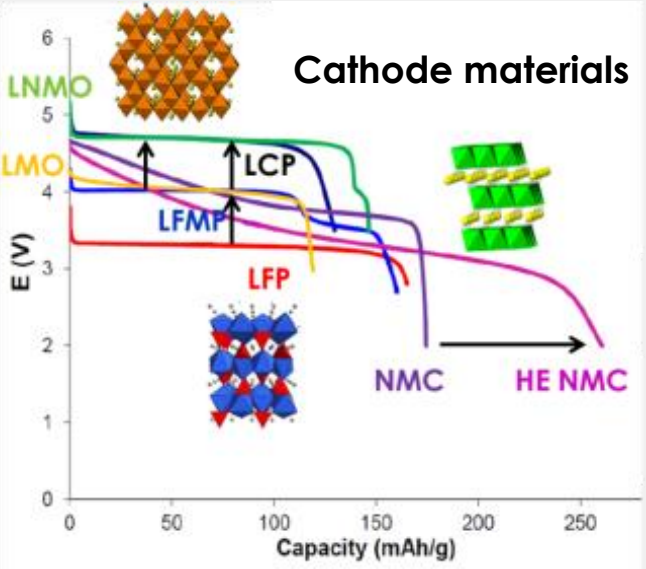
In a 3 year horizon, advanced Li-ion!

Despite continuous news flow announcing revolutionary new rechargeable technologies, there is no new breakthrough rechargeable systems on this horizon level

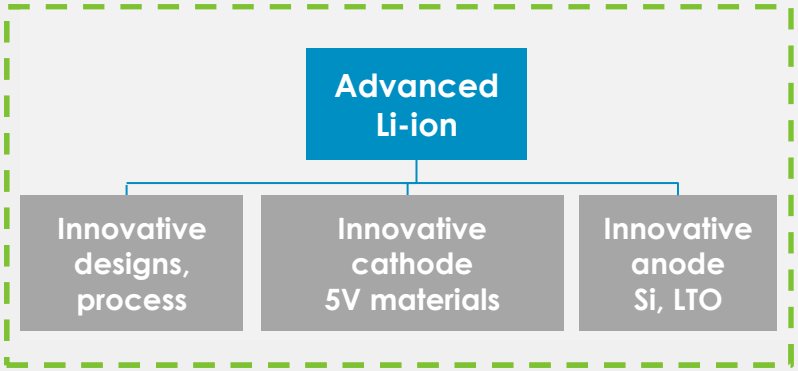
Advanced Li-ion chemistries

Near term : incremental improvement of Li-ion technologies (Wh/l, Wh/Kg, W, cost)

- Increase **volumetric/specific energy** while keeping **long life**
- Enhance **charge** and **cycling** capabilities
- And of course reduce **cost**, while maintaining or improving the **safety**



1-3 years horizon

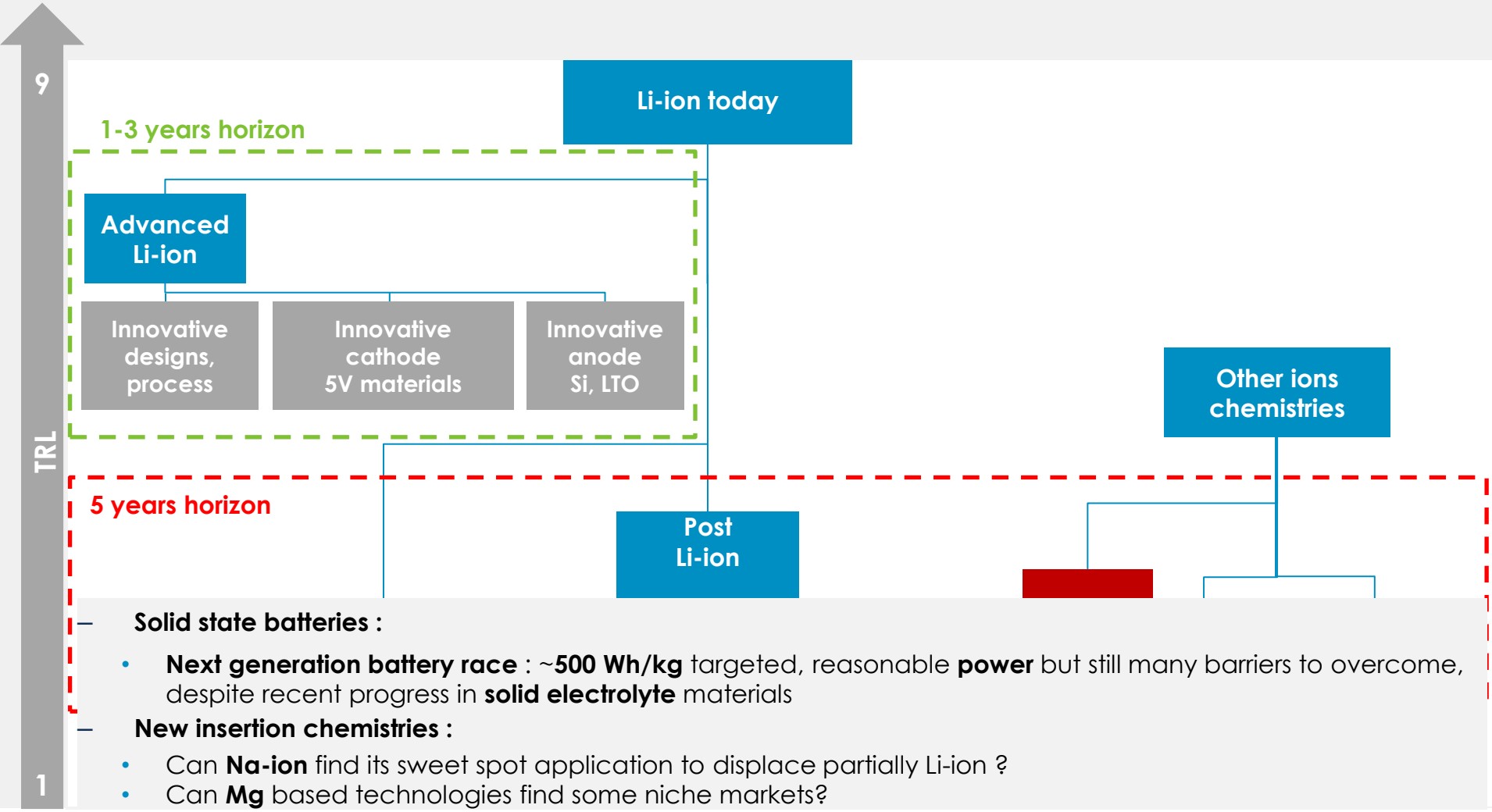


Innovations on materials, process, designs

- **Anode** materials : **high capacity Si** based materials : **SiO_x, Si/C**
- **Cathode** materials : **HV** materials in the **olivine** family, **Mn-rich** in the lamellar family, **HV others**
- **Enabling non active components** : **electrolytes**, **binders, separator, foils**
- **Disruptive processes** : water based for reactive cathodes, thick electrodes, new processes

Post Li-ion chemistries

Post Li-ion : SAFT is investing in or following key disruptive battery technologies (Wh/l, Wh/Kg, cost)



- **Solid state batteries :**
  - **Next generation battery race** : ~**500 Wh/kg** targeted, reasonable **power** but still many barriers to overcome, despite recent progress in **solid electrolyte** materials
- **New insertion chemistries :**
  - Can **Na-ion** find its sweet spot application to displace partially Li-ion ?
  - Can **Mg** based technologies find some niche markets?

Multi-scale characterization techniques

State-of-the-art characterizations from the **atomic to electrode scale**, **ex-situ** or **in-operando**, on **pristine** and **aged cells (Post -mortem) are key enablers** for deep understanding and quick improvement loops

STEM HAADF, ABF, XPS, ToF SIMS, XAS, Mossbauer

Neutron diffraction, PGSE NMR, RPE

XRD 3D detector, In operando XRD, SAXS

Electrical tests, GITT, Impedancemetry…

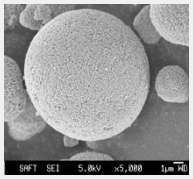
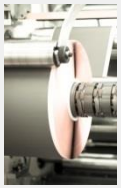
DLS, Laser granulometry

Hg porosimetry, BET

Schottky FEG SEM with SDD EDS, Ar beam cross polisher

XRF, ATR FTIR, ICP, DSC, ATG, Tensiometer, Goniometer, Pycnometer, GCMS, Rheometer, Microcalorimeter,…

1Å 10nm 1µm 0.1mm 1cm 1m

Functionalized materials	Electrodes	Cells	Battery system
			
Atomic structure, composition, texture Powder characteristics Surface characteristics	Process steps characterizations Electrode characteristics porosity, tortuosity, wettability	Rate capability Calendar and cycle ageing Self discharge	Thermal Mechanics BMS

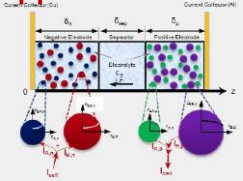
Battery management and modelling

Accelerate and optimize cells, modules, batteries development

TRL

1 Multiscale Multiphysics Models

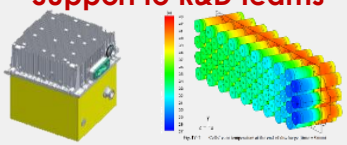
Support to R&D teams



- Prospective embeddable "reduced" multiphysics models
- Ageing models based on mechanistic laws

Safety thermal

Support to R&D teams



- 3D fluidic/thermal, mechanical modelling, safety assessment
  - Thermal management at cell/module/battery level, Safety

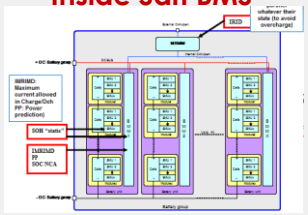
Saft battery models

Support for Saft offers

- Cell, battery performances prediction
  - Li-ion multi-chemistries (NCA, NMC, LFP) : Lifetime, power assessment
    - SOC (State of charge)
    - SOH (State of health), SOL (State of life) : ageing, system scattering
    - SOP (State of power) : power prediction, pulse management
  - Battery architecture management
    - Balancing strategies at module/battery level

9 Embedded libraries

Inside Saft BMS



- Algorithm / embedded libraries inside BMS