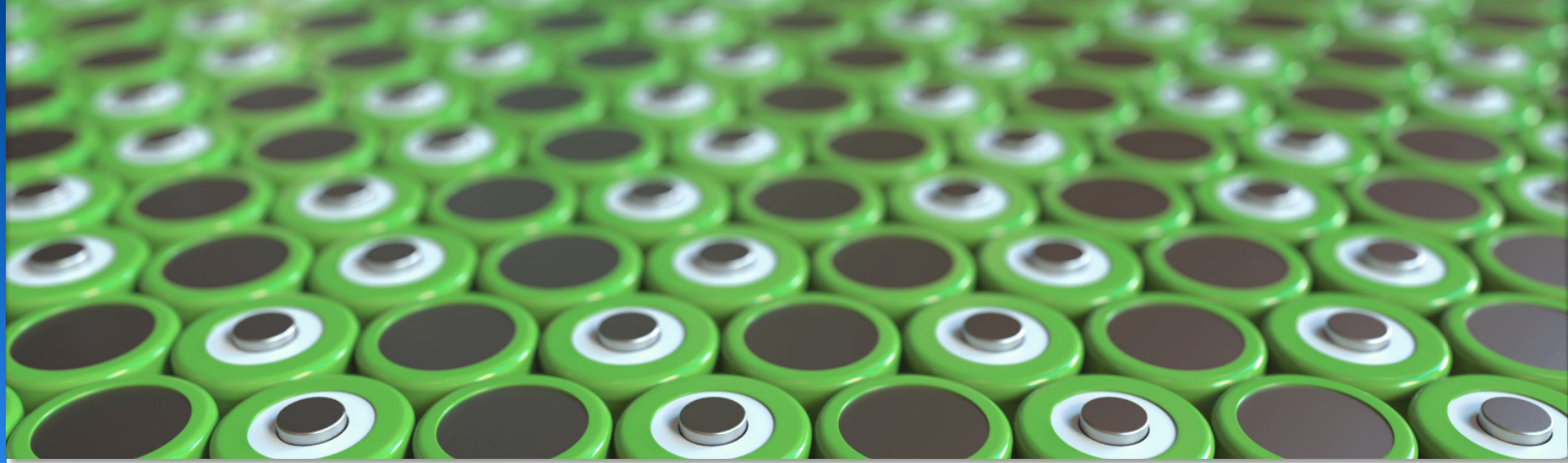


Simon Taylor
Battery Business
Development
28 Sept 2023
Battery Tech Expo,
Gothenburg



Boosting Product Quality at Scale

Analytical Chemistry's Crucial Contribution

METTLER **TOLEDO**



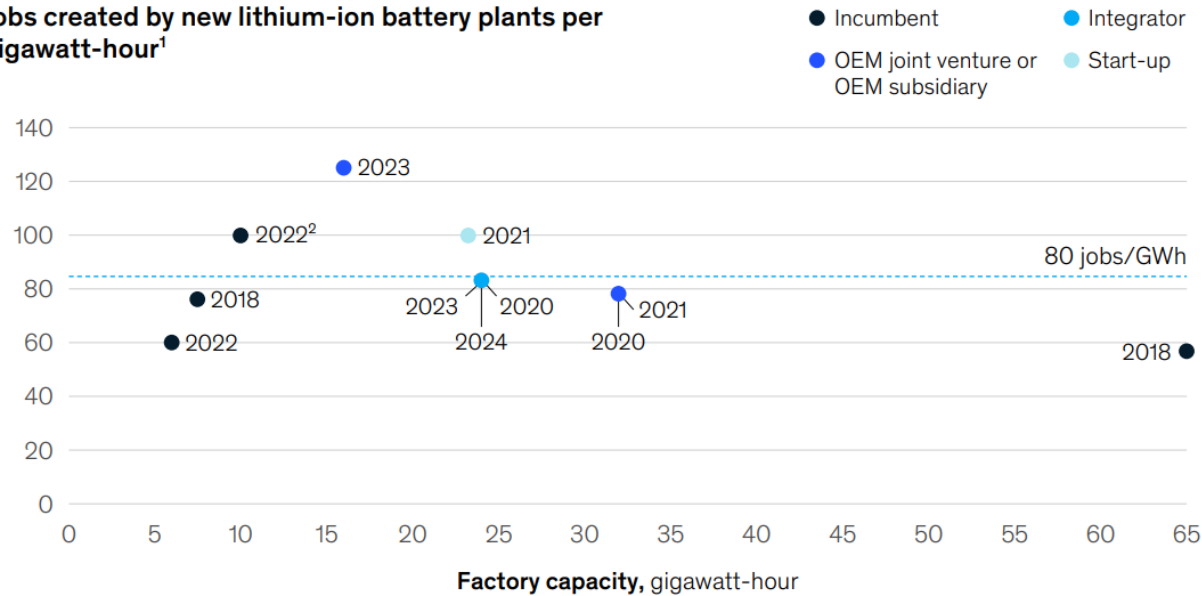




Critical skills missing for 250,000+ new jobs to be created by 2040

On average, new battery factories add approximately 80 jobs for every gigawatt-hour of capacity.

Jobs created by new lithium-ion battery plants per gigawatt-hour¹



¹Comparability of indications is limited due to differences in value-chain coverage—for example, battery-cell production only versus local module and pack production or colocation of R&D facilities. In general, values refer to the overall number of jobs.

²Years denote start of production.
Source: Press search

	Cell and Component Manufacturing (electrodes, electrolytes, modules, packs)	Raw Materials, Refinement, and Recycling
Electrochemistry, Battery Chemistry	88%	71%
Battery materials (chemical engineering, materials science)	74%	79%
Mining	3%	32%
Electrical	41%	4%
Power Electronics	26%	7%
Software/BMS	41%	21%
System Design	50%	21%
Prototyping	38%	14%
Battery testing	41%	18%
Safety (electrical, fire, hazmat, etc.)	29%	11%
Application of batteries (installation, operation, etc.)	29%	7%
Operation and maintenance	26%	7%
Battery recycling	18%	43%
Environmental engineering	12%	14%
Project management	26%	25%
Technical lead, manager	47%	25%
Supply chain management	29%	32%
Manufacturing (incl. plant design)	50%	29%

1 Warm-up

2 Introduction to METTLER TOLEDO

3 Strategies to Scale Your Laboratory & Workflows

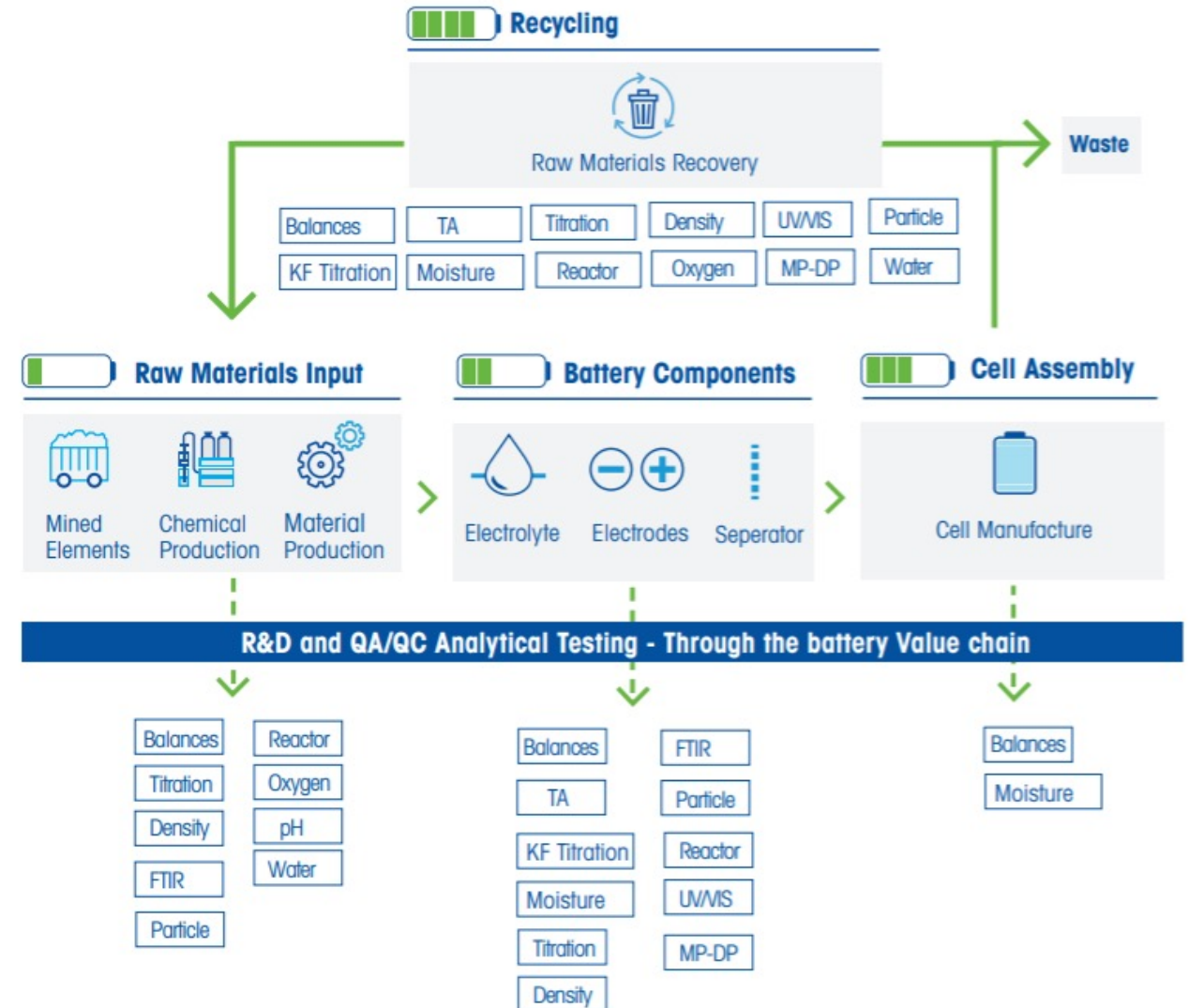
4 Scaling Your Employees

5 Summary

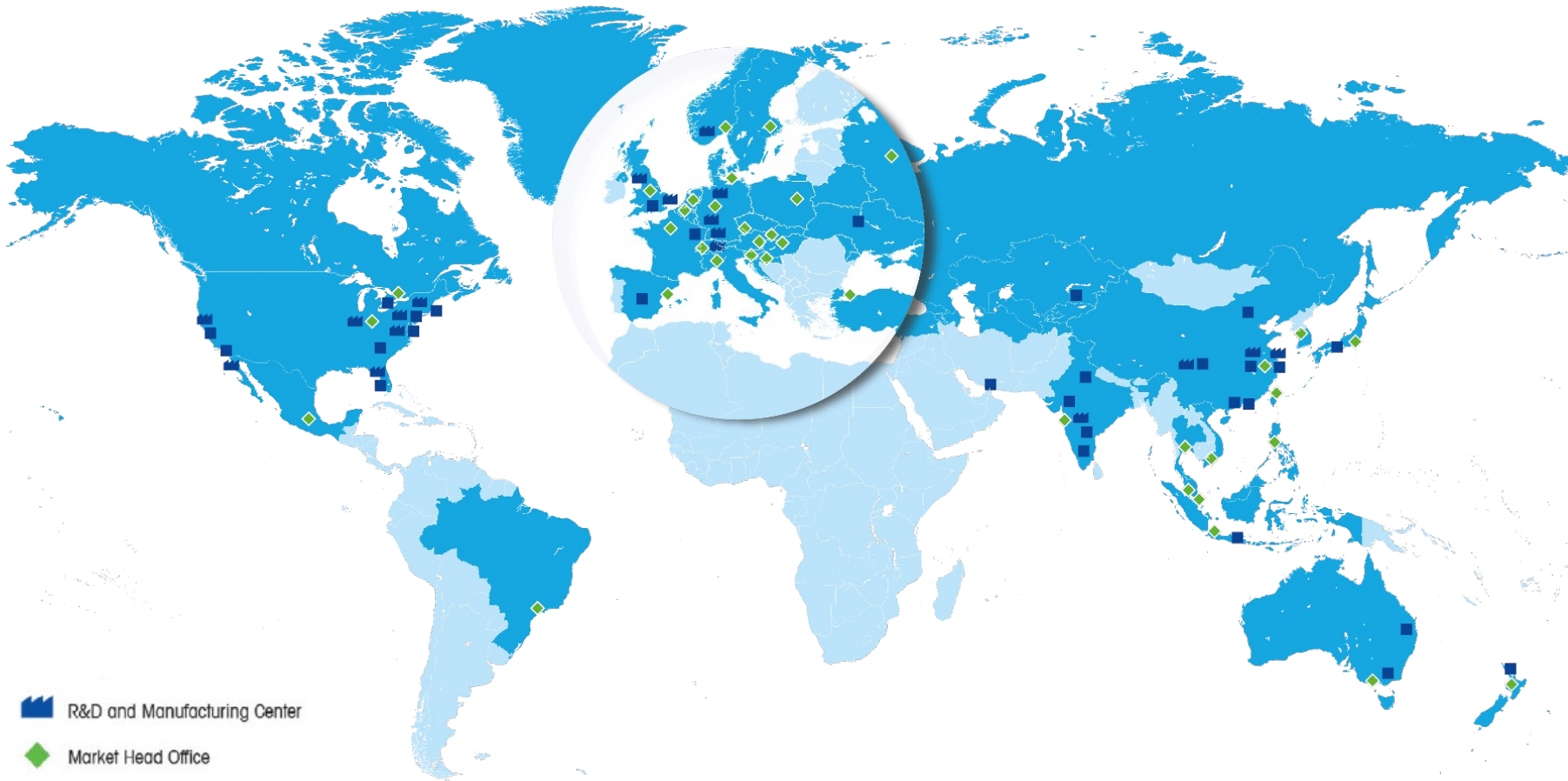
From Mining to Recycling – MT Provides Measurement Solutions Across the Supply Chain

METTLER TOLEDO Solutions help to:

- Streamline processes
- Enhance productivity
- Ensure accurate results
- Reach compliance with regulatory requirements
- Optimize costs and reduce waste



METTLER TOLEDO: Your Trustworthy Partner



Global Presence

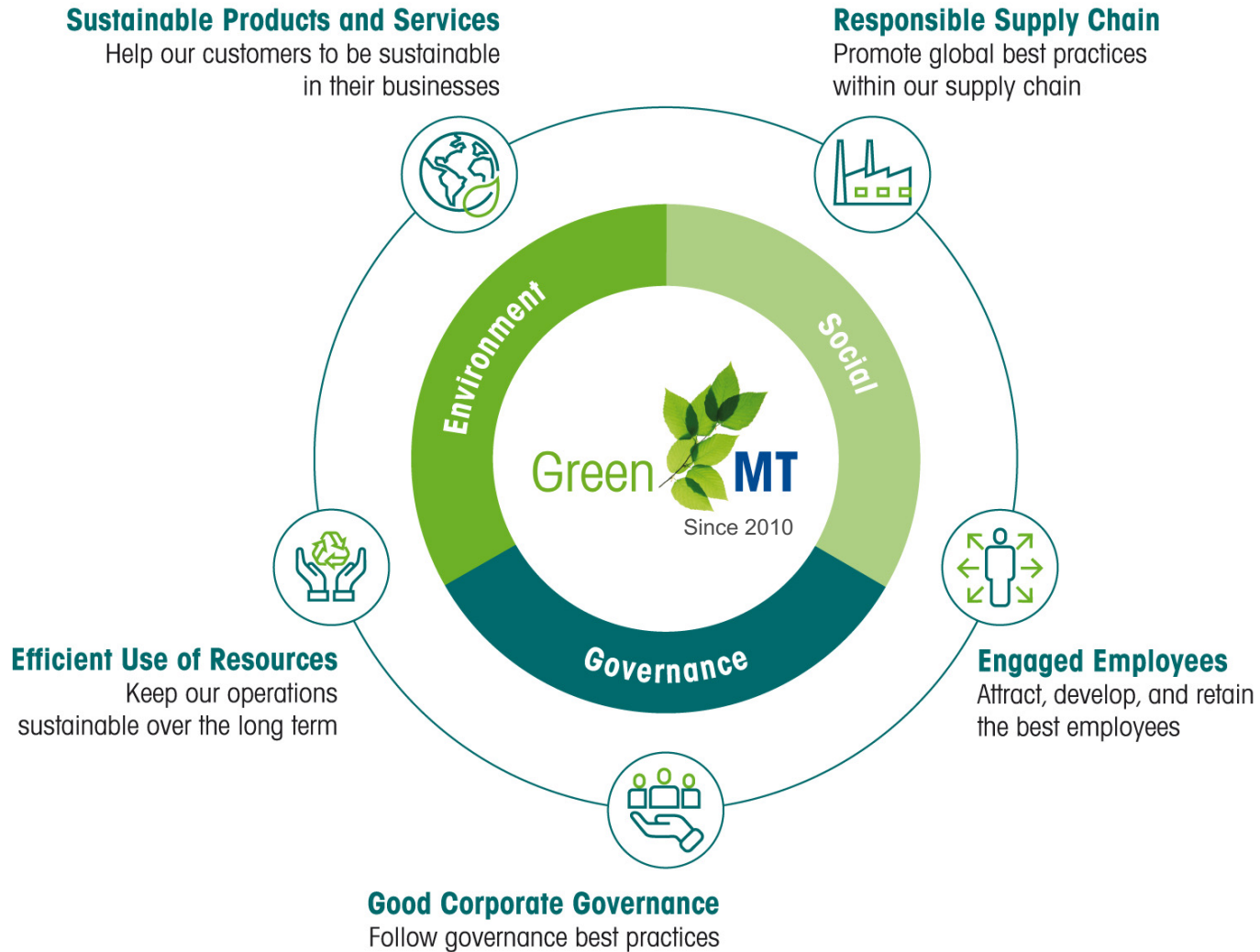
Largest service force of certified technicians within the industry.

50+ country coverage

1500+ Service Technicians

Acknowledged for Accuracy

METTLER TOLEDO Services ensure that your equipment is always operating at peak performance so that your measurements meet productivity, quality and regulatory requirements.



Zero Waste to landfill 2025



Responsible Sourcing



Carbon neutral operations



100% Renewable Electricity



Approved Net Zero Targets



Climate Score B



Gold Medal

Addressed UN Sustainable Development Goals



More information at www.mt.com/sustainability

Scaling throughput, scaling workflows, scaling people

Scale Quality Control



- Implement robust systems
- Automate daily Tasks
- Reduce human errors
- Establish a culture of quality

Optimizing Workflows



- Identify and streamline processes
- Digitalize workflows across areas
- Improve collaboration and communication

Hiring and Training Talent



- Provide comprehensive onboarding training
- Offer ongoing specialized training & development
- If possible: Hire talent with existing specific skills

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Identifying the 8 wastes is your first step to productivity gains

Reduce or eliminate the 8 Wastes:

Defects

Overproduction

Waiting Time

Not engaging all Employees

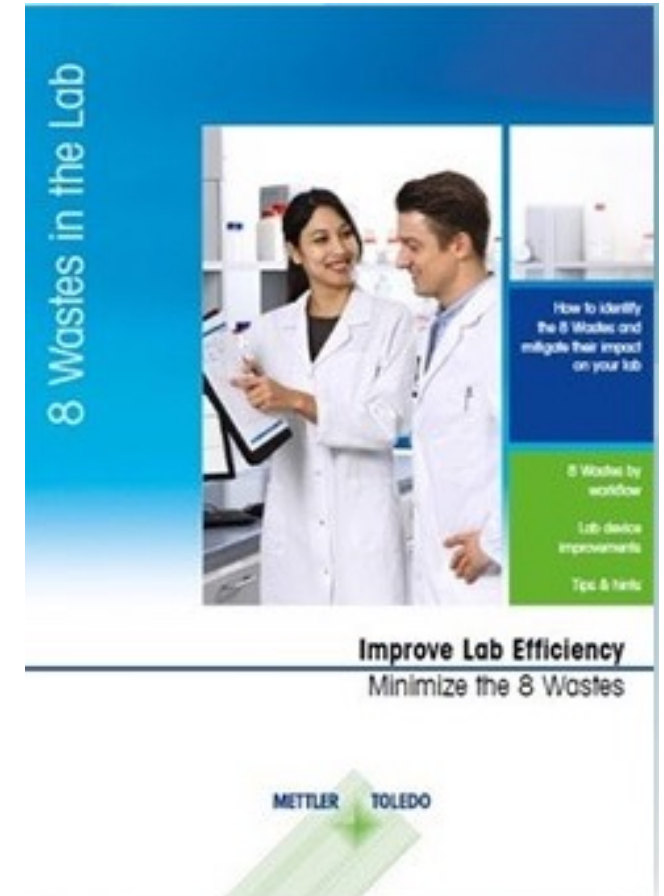
Transportation

Inventory

Motion / Distances

Extra Processing

(TIMWOODS equivalent)



[mt.com/Library](https://www.mt.com/Library)

Save time by using AI to autonomously evaluate your thermal curves

Evaluating thermal analysis results leaves many analysts questioning:

- What is the **type** of effect?
- Where does the effect **begin** and **end**?

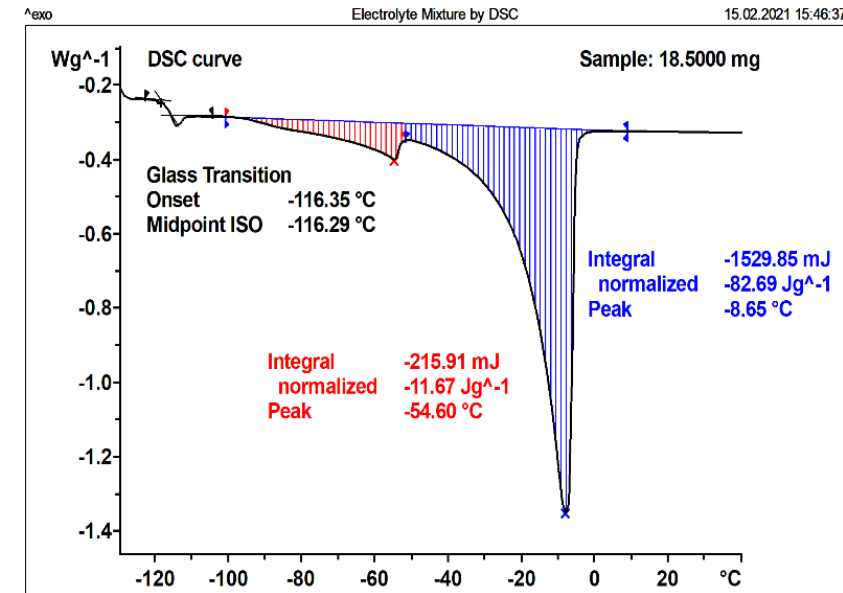
Our **AIWizard™** answers these questions - even for complex curves.

- **All thermal effects are recognized**
 - AIWizard **standardizes the analysis**, producing consistent results
 - AIWizard **uses adaptable, trainable neural networks**



Did You Know?

A METTLER TOLEDO industry survey uncovered that The percentage of customers that spend too much time on data evaluation and documentation is **63%**



AIWizard Generated Evaluation




DSC 3+ & AIWizard Software

How to scale your workflow from a single instrument, to a workhorse

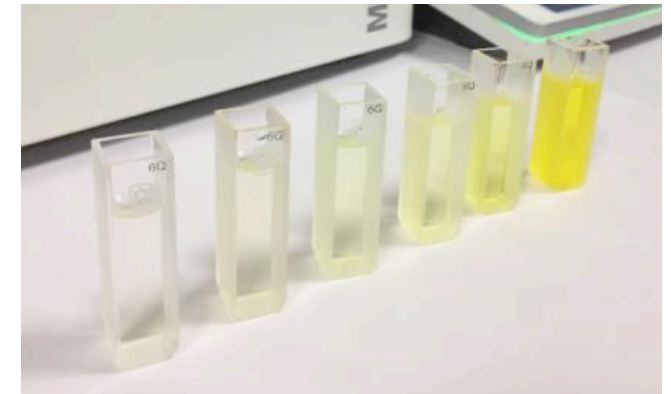
- Electrolyte solutions are often unstable, and susceptible to rapid ageing
- They change color and often turn turbid – even after very short atmospheric exposures
- Traditional color measurements use pre- defined liquid standards or a printed color scale

Challenges:

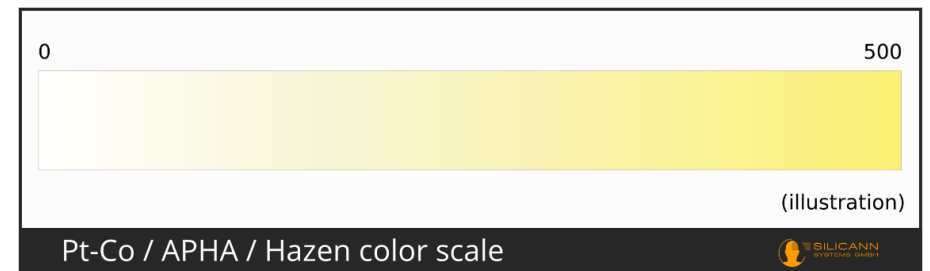
- This measurement is only partially reliable, the result is influenced by:
 - Lighting conditions
 - The size of the vessel surface
 - The cleanliness of the vessel
 - The subjective opinion of the observer, and
 - The mood of the observer



Did You Know?
~9% of people have a form of color vision deficiency



PLATINUM-COBALT COLOR SCALE (ABBREVIATED: PT-CO COLOR SCALE, DEPRECATED: HAZEN ODER APHA COLOR SCALE)



Spectroscopy is the accurate way to monitor electrolyte solution ageing, with built-in color scales

- Instruments: **UV/Vis Excellence UV7**
- Samples: **Electrolyte (liquid)**
- Calculation: **APHA Pt-Co Hazen color scale**
CIELAB color scale
- Application notes available:
 - [APHA Color Determination](#)
 - [CIELAB Color Measurement](#)



Easy UV and Easy Vis



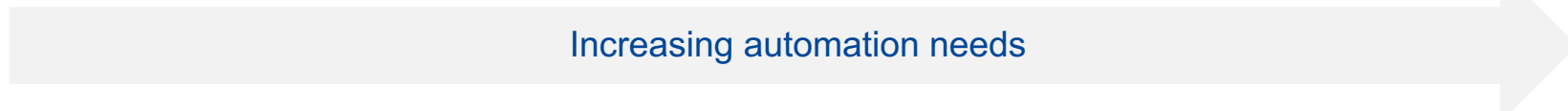
Standalone UV5 UV/Vis



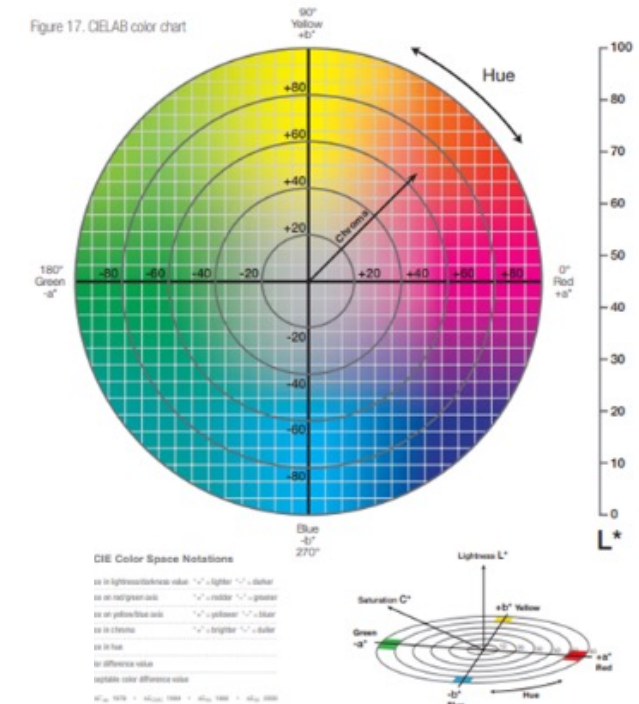
UV/Vis with 8-sample cuvette changer



UV/Vis with InMotion and Fiber Probe



Increasing automation needs



Multiparameter measurements reduce hands-on technician time by 70%

- Parallel determination
- Reduce operator involvement by up to 70%
- No human intervention required for d, n, CIELAB, APHA and/or YI
- Ensures sample integrity
- Unified / single report with LabX™ software

- **Add pH / COND / Titration instruments if needed**

- Other applications:
 - Slurries
 - Wastewater
 - Raw / Incoming materials control



Sample	d ²⁰ [g/cm ³]	n _D ²⁰	CIE: L / a* / b*	APHA	YI
Li-e 1.	1.27248	1.40064	99.9 / 0.7 / 0.2	8.9	0.5
Li-e 2.	1.27247	1.40065	99.9 / 0.9 / 0.1	5.1	0.2
Li-e 3.	1.27248	1.40065	99.6 / 0.9 / 0.2	7.7	0.4
Li-e 4.	1.27246	1.40064	99.8 / 0.7 / 0.2	5.3	0.3
Li-e 5.	1.27249	1.40065	99.9 / 0.8 / 0.1	5.1	0.3
Li-e 6.	1.27248	1.40063	99.9 / 1.1 / 0.2	5.1	0.2
NMP 1.	1.03239	1.47082	99.8 / -0.8 / 2.1	67.2	3.6
NMP 2.	1.03238	1.47082	100.5 / -0.8 / 2.3	74.2	3.9
NMP 3.	1.03239	1.47082	99.9 / -0.8 / 2.2	68.7	3.6
NMP 4.	1.03238	1.47082	100.1 / -1.0 / 2.4	73.1	4.0
NMP 5.	1.03238	1.47082	100.6 / -1.0 / 2.1	65.1	3.5
NMP 6.	1.03239	1.47082	100.5 / -0.7 / 2.2	70.6	3.7

Table 1: Density (d²⁰), refractive index (n_D²⁰) and color CIELab, APHA and Yellowness Index mean value and standard deviation (indicated by s) results of different samples of lithium-electrolyte (Li-e) and N-methyl-2-pyrrolidone (NMP).

Increased Lab Productivity

Speed up Your Daily Work

- Increase efficiency and traceability with automatic and real-time capture of **complete centralized data and reporting**
- Prevent time-consuming rework: **Block out-of-specs instruments.**
- Automatically **calibrate and/or test instruments and trigger service reminders**
- **Develop your workflows in LabX™ only once** and deploy to all connected instruments
- Speed up your workflows with step-by-step **user guidance** and **multi-parameter** solutions
- Be future-ready for **industry standards** – LabX supports your compliance needs



One Software Solution for METTLER TOLEDO Instruments Covers >40% of Typical Laboratory Instruments



- 1** Warm-up
- 2** Introduction to METTLER TOLEDO
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The most common questions I heard this year...

“What can you tell us that’s new?”

“What should we be testing for, and how?”



METTLER TOLEDO is proud of our global product specialists, application and service teams

For a full list of our training courses: Contact your local office:



mt.com → Contact Us

For all our battery collection page and applications:



mt.com/li-ion-battery

mt.com/Applications

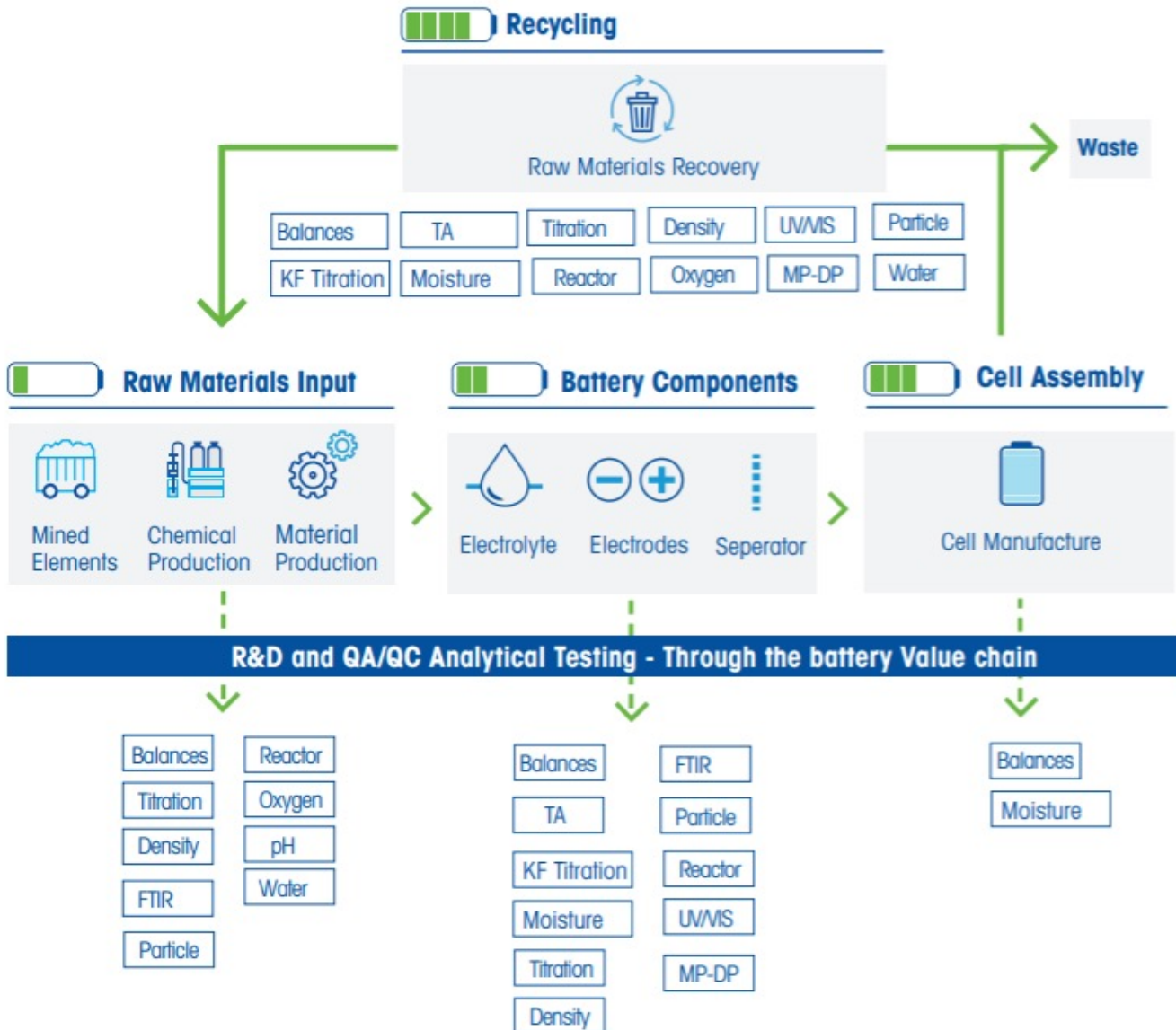
For our Expertise Library - for training material, basics of chemistry, instrument guides and much more)



mt.com/Library

Description	Basic	Advanced	Expert	Customized
Basic & Functional Operation - Instruments	X	X	X	X
EduPac Document & Certified training	X	X	X	X
Care, Maintenance & Troubleshooting		X	X	X
GxP Hints & Tips		X	X	X
LabX Overview		X	X	X
Full GxP for specific Instruments			X	X
How to build a method			X	X
Detailed Application Theory & Calculations			X	X
Method development**				X

Example training offering for Analytical Chemistry instruments from MT



Balances

- Sample preparation, Formulation, Check-weighing

Thermal analysis

- TGA and DSC : heat capacity, decomposition temperatures, enthalpy
- TMA and DMA : thermal, mechanical and physical properties

Karl Fischer Titration and Moisture Analyzer

- Water and moisture content of battery components and raw materials

Titration

- Determination of purity/impurity of metals and active materials
- HF content determination through acid-base titration

Autosampler (InMotion)

- Improve process efficiency, safety, and throughput.

UV/Vis

- Anions, non-metal elements, color and degradation analysis

Density and Refractometry

- Quality control of incoming goods and recycled chemicals

Oxygen pH and Conductivity

- Ensure inert working conditions and control particle size distribution in PCAM coprecipitation

FTIR (ReactIR)

- Monitor chemical reactions and give real-time insights

Automated Reactors

- Calorimetry measurements and data recording for process understanding and control

Melting Point and Dropping Point

- Dropping point of anode materials
- Softening point of pitch for anode manufacturing

Water

- Monitor ultrapure water and ensure the highest quality is delivered

Particle analyzer (Particle Track)

- Monitor and characterize crystallization reactions, particle size, and particle size distribution.

Backups – Application Coverage

	Battery materials	Analysis
Anode	<ul style="list-style-type: none"> Graphite, petroleum coke Lithium titanate, LTO ($\text{Li}_4\text{Ti}_5\text{O}_{12}$) 	<ul style="list-style-type: none"> Water determination by KF Titration: C30S + InMotion KF Electrode slurry (Graphite surface modification): DP70/90.
Electrolyte	<ul style="list-style-type: none"> Salt: Lithium hexafluorophosphate, LiPF_6 Solvents e.g. <ul style="list-style-type: none"> Ethylene carbonate, EC ($(\text{CH}_2\text{O})_2\text{CO}$) Ethyl methyl carbonate, EMC ($\text{C}_4\text{H}_8\text{O}_3$) Additive: <ul style="list-style-type: none"> Vinylene carbonate, VC ($(\text{CHO})_2\text{CO}$) 	<ul style="list-style-type: none"> Water determination by KF Titration:: C30S (direct injection) HF (free acid) and Cl^- - Titration Excellence Density – Density Excellence/Densito Conductivity – Tx with CB, Seven product portfolio Color of electrolyte – UVVIS
Separator	<ul style="list-style-type: none"> Polypropylene, PP, or polyethylene, PE 	<ul style="list-style-type: none"> Water determination by KF Titration: C30S + InMotion KF
Cathode	<ul style="list-style-type: none"> Lithium carbonate, Li_2CO_3 Lithium hydroxide, LiOH Lithium chloride, LiCl <hr/> <ul style="list-style-type: none"> Lithium manganese oxide, e.g. LiMn_2O_4 (LMO) Lithium cobalt oxide, LCO (LiCoO_2) Lithium nickel-cobalt-aluminum, NCA ($\text{LiNi}_x\text{Co}_y\text{Al}_z\text{O}_2$) Lithium iron phosphate, LFP (LiFePO_4) 	<ul style="list-style-type: none"> Li_2CO_3, CO_3^{2-}, LiOH, LiCl – T5/T7/T9 Al, As, Fe, Si, SiO_4^{2-} - UV/Vis F^- : Titration Excellence/ISE <hr/> <ul style="list-style-type: none"> Water determination by KF Titration: C30S + InMotion KF Co, Mn, Ni, Fe, Li, Al - Titration Excellence PO_4^{3-} : UV/Vis

Applications

Water content	Water, H ₂ O	Solids, electrolyte	M808 , M820	KF
Free acid	Hydrofluoric acid, HF	Electrolyte	M813	GT Acid/Base
Alkali content	Lithium carbonate/hydroxide, Li ₂ CO ₃ LiOH	Electrolyte	M828	
Lithium purity	Lithium, Li	LiOH	M874 , M875	
Total metal content	Nickel, manganese, cobalt	NMC cathode material	M832	GT Complexometry
Cobalt content	Cobalt, Co	LiCoO ₂ cathode	M829	
Manganese content	Manganese, Mn	NMC cathode material	M833	GT Redox
Cobalt and nickel	Cobalt, Co and nickel, Ni	NMC cathode material	M834	
Iron content	Iron, Fe	LiFePO ₄ cathode	M831	
Lithium content	Lithium, Li	LiOH, electrolyte	M865	GT Precipitation
Chloride content	Chloride, Cl ⁻	Li-Battery materials	M830	
Density	Density of Electrolytes	Electrolyte, solvents	DERE0001	DE
Softening Point - SP	Softening point of electrode pitch/slurries	Anode, cathode mat.	SP-QC	DP
Conc. determination and monitoring	Metal ions, organic solvents – time dependence of absorption spectra	Anode, cathode mat., electrolyte	UVVIS-Fe	UV/Vis
Color	Color determination	Electrolyte	UVVIS-Color	

Main Components of a Battery

Battery Component	Application
Anode, cathode	Thermal stability, decomposition behavior, decomposition products
Electrolyte	Melting, crystallization, water content, decomposition, decomposition products
Binder	Glass transition, melting, crystallization
Separator	Thermal stability, melting, crystallization, expansion, mechanical behavior in fluids

Battery Housing	Application
Plastic materials, metals	Thermal stability, decomposition behavior, decomposition products, melting, crystallization