Roadmap for leveraging Smart Buildings

A practical roadmap for achieving asset management goals through data-driven building solutions

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Roadmap for leveraging Smart buildings
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BRAINS 4 BUILDINGS

Executive summary

This handbook provides a practical roadmap for facility managers, particularly those without technical expertise, to leverage data-driven solutions in achieving asset management goals through smart buildings. The roadmap describes the optimalisation of existing BMS systems, as well as the steps towards integrating data from various sources to be able to develop advanced algorithmics.

Key Objectives:

1. **Raise Awareness**: Highlight current industry challenges and demonstrate how both high-tech and low-tech solutions can be employed to overcome these challenges.
2. **Tool for Asset Management**: Emphasize that smart buildings are not an end goal but a means to achieve predefined asset management objectives. Various tools are proposed to execute the discussed steps in the flow towards data integration.
3. **Stakeholder Guidance**: Offer a step-by-step guide for various stakeholders involved in the smart building value chain, from asset owners to service providers, to collaboratively achieve these goals.

Highlights:

- **Strategic Roadmap**: Provide a clear roadmap outlining the steps from setting asset management goals to implementing data-driven solutions and improving existing systems.
- **Real-World Examples**: Include specific examples and case studies to showcase the successful application of smart building technologies in real scenarios.
- **Societal Impact**: Address how smart buildings can contribute to reducing energy consumption and CO_2 emissions, aligning with broader sustainability goals.
- **Data Integration**: Illustrate the importance of integrating various data sources (e.g., BMS, LMS) to optimize building operations and energy efficiency.

By following this handbook, facility managers can better understand how to utilize data and smart building technologies to enhance operational efficiency, achieve sustainability targets, and improve overall asset management. By following the roadmap, the readers end up with an integrated database which is needed to start developing advanced building specific algorithms like FDD and MPC.

Why a smart building? – societal challenges

Duurzaamheid • 31 aug 11:52 • Aangepast op 31 aug 13:16

Waarde niet-duurzame kantoorpanden met 40 procent gedaald

Auteur: Robert van Loon

Vertraging nieuwbouw, stop op laadpalen: ook in Arnhem dreigt overbelasting van stroomnet

Arnhem gaat in kaart brengen wat de overbelasting van het elektriciteitsnetwerk betekent voor de stad. Door een tekort aan stroom kunnen bijvoorbeeld woningbouwprojecten en nieuwbouw van scholen en bedrijven vertraging oplopen. Ook dreigt het maximum aantal laadpalen in de stad voor elektrische auto's in zicht te komen, indien er geen aanvullende maatregelen volgen.

Stephen Friedrichs 11-11-23, 10:52

12:21 • Aangepast op 16 dec

ING sluit hoofdkantoren op vrijdag vanwege lage bezetting

NOS Nieuws • Dinsdag 18 oktober 2022, 17:42

Helft kantoorgebouwen voldoet niet aan energiezuinige norm

Ongeveer de helft van de kantoren in Nederland voldoet niet aan de eisen voor energiezuinigheid. Per 1 januari

Home › 70% van koelinstallaties werkt niet optimaal

70% van koelinstallaties werkt niet optimaal

Plus Damprijs

'Duurzaamheid gaat over intelligentie, niemand wil een dom gebouw'

Kantoorbezetting bij KPN 20%, 54.000 m2 vastgoed afgestoten

Why a smart building? – societal challenges

In the Netherlands, the built environment is responsible for 30-40% of energy consumption and nearly one-third of CO_2 emissions[1]. In recent years, various forms of legislation have been implemented with the aim of encouraging these 'large consumers' to actively reduce their emissions (energy labels, the Paris Proof agreement, EED, EPBD IV, EML, GACS, BENG). Despite all this legislation, we are still far from achieving the goals outlined in the Paris Proof agreement. In fact, a quarter of the buildings (23%; over 4,000 office buildings in the Netherlands) do not even meet the label C requirement imposed in 2018[2].

Research shows[3] that making a building 'smarter' is one of the most important and effective measures to achieve the sustainability goals and to give substance to the big social challenges we face.

European Commission

[1] Global Status Report for Buildings and Construction 2019 – Analysis – IEA
[2] Openbare data energielabels - EP-Online
[3] Why Smart Buildings Are A Smarter Choice (forbes.com)

EPBD: eisen aan gebouwen

Iedereen die actief is op het terrein van de gebouwde omgeving moet voldoen aan de Nederlandse eisen die voortkomen uit de **Europese Energy Performance of Buildings Directive**, of kortweg: **EPBD**. De richtlijn bevat eisen en bepaling om de energie-efficiëntie van gebouwen te verbeteren, waardoor het energiegebruik daalt. De eisen en bepalingen die relevant zijn voor de Nederlandse situatie zijn opgenomen in het Bouwbesluit en de Regeling Bouwbesluit. Ook de Rijksdienst voor Ondernemend Nederland (RVO) biedt meer informatie over de EPBD.

Rijksoverheid

	EIS/VERPLICHTING	VAN TOEPASSING OP	TOELICHTING	HULPMIDDELEN Klik op de regeling of checklist!
1	Energieprestatie-eisen en documentatie	• Installatie van nieuwe systemen[1] • Vervanging van de centrale opwekker[2] • Vervanging van 1/3 of meer van de afgiftelichamen[3]	De eisen en bijbehorende rekenregels staan in de Regeling Bouwbesluit en op de EPBD pagina van RVO. Controle gebeurt aan de hand van de documentatie van de installateur. Zonder documentatie kan vaak met een speciale checklist worden nagegaan of het systeem voldoet aan de eisen. In andere gevallen is een nieuwe berekening nodig. Voor complexe situaties is een NTA-berekening in een NTA-rekentool nodig. De installateur moet de documentatie aan de gebouweigenaar afgeven.	• Meer gedetailleerde informatie en de rekentool staan op de EPBD pagina van RVO • Bepalingsmethode NTA 8800
2	Systeemeisen	• Installatie van nieuwe systemen[1] • Vervanging van de centrale opwekker[2] • Vervanging van 1/3 of meer van de afgiftelichamen[3]	Voor elk type installatie zijn in de Regeling Bouwbesluit eisen vastgelegd voor het op de juiste manier installeren, dimensioneren, instellen en bedienen van de systemen. De eisen voor het inregelen van verwarmingssystemen zijn samengevat in de checklist 'EPBD: eisen voor de plaatsing van thermostatische regelingen en waterzijdig inregelen'.	• Meer gedetailleerde informatie staat op de EPBD pagina van RVO • EPBD: eisen voor de plaatsing van thermostatische regelingen en waterzijdig inregelen
3	Verplichte installatie van thermostatische bediening in alle ruimtes[4]	• Installatie van systemen voor verwarming en/of koeling in nieuwe gebouwen • Vervanging van de centrale opwekker[2] • Vervanging van 1/3 of meer van de afgiftelichamen[3]	Nieuwe gebouwen moeten altijd voorzien zijn van thermostatische regelingen, voor zowel verwarming als airconditioning. In de checklist 'EPBD: eisen voor de plaatsing van thermostatische regelingen en waterzijdig inregelen' staat wanneer voor bestaande gebouwen installatie vanuit het Bouwbesluit verplicht is. De verplichting geldt niet voor gebouwen, verblijfsruimtes of verblijfsgebieden die niet verwarmd en/of gekoeld worden. Of als de meerkosten meer dan 20 procent van de totale installatiekosten bedragen. Als aan elkaar grenzende ruimten onderdeel zijn van dezelfde thermische zone mag de zelfregelende apparatuur de temperatuur ook per zone (verblijfsgebied) reguleren.	• Meer gedetailleerde informatie staat op de EPBD pagina van RVO • EPBD: eisen voor de plaatsing van thermostatische regelingen en waterzijdig inregelen
4	Verplichte keuring van verwarmings- en airconditioningsystemen	• Systemen met een vermogen van meer dan 70 kW	Verwarmingssystemen moeten eens in de vier jaar worden gekeurd en airconditioningsystemen eens in de vijf jaar. De verplichting vervalt voor gebouwen met gebouwautomatisering en -controlesystemen (GACS) en/of een energieprestatiecontract. Van elke keuring wordt voor eigenaar of huurder een keuringsrapport opgesteld. Keuringen moeten binnen 4 weken af worden gemeld in de betreffende meldingsregisters. De keuringsplicht staat samengevat in de checklist 'EPBD: keuringsplicht energieprestatie'.	• Meer gedetailleerde informatie staat op de EPBD pagina van RVO • EPBD: keuringsplicht energieprestatie
5	Vanaf 2026 verplichte installatie van Gebouw-automatiserings- en controlesystemen (GACS)	• Utiliteitsgebouwen met verwarmings- en airconditionings-systemen met een vermogen van meer dan 290 kW[6]	De GACS moeten onder andere in staat zijn het energieverbruik permanent te controleren en bij te sturen, de energie-efficiëntie van het gebouw te toetsen en de communicatie met verbonden systemen en andere apparaten mogelijk te maken. De precieze eisen waaraan GACS moeten voldoen staan op de EPBD pagina van RVO.	• Meer gedetailleerde informatie staat op de EPBD pagina van RVO
6	Verplichte installatie van laadinfrastructuur voor elektrisch vervoer (meer dan 10 parkeerplaatsen)	• Nieuwe utiliteitsgebouwen of woningen of bestaande utiliteitsgebouwen of woningen die ingrijpend worden gerenoveerd met meer dan 10 parkeerplaatsen[7]	De verplichting geldt wanneer de parkeergelegenheid op hetzelfde terrein (bouwperceel) ligt. Bij woningen is het verplicht elke parkeerplaats te voorzien van leidingdoorvoeren (loze leidingen). Bij utiliteitsgebouwen is het verplicht minimaal een laadpunt te installeren en minimaal 1 op de 5 parkeerplaatsen te voorzien van leidingdoorvoeren (loze leidingen). De precieze eisen waaraan laadpunten moeten voldoen staan op de EPBD pagina van RVO.	• Meer gedetailleerde informatie staat op de EPBD pagina van RVO
7	Verplichte installatie van laadinfrastructuur voor elektrisch vervoer (meer dan 20 parkeerplaatsen)	• Bestaande utiliteitsgebouwen met meer dan 20 parkeerplaatsen	De verplichting geldt wanneer de parkeergelegenheid op hetzelfde terrein (bouwperceel) ligt. Bij bestaande utiliteitsgebouwen met meer dan 20 parkeerplaatsen is met ingang van 1 januari 2025 minimaal één oplaadpunt verplicht. De precieze eisen waaraan laad-punten moeten voldoen staan op de EPBD pagina van RVO.	• Meer gedetailleerde informatie staat op de EPBD pagina van RVO

Categorie 1 t/m 3: gebouweigenaren, installateurs, bevoegd gezag, installatieadviseurs, corporaties, verhuurders, huurder/gebruiker
Categorie 4: gebouweigenaren, installateurs, keuringsinstanties, bevoegd gezag, verhuurders, huurder/gebruiker
Categorie 5: gebouweigenaren, bevoegd gezag, keuringsinstanties, installateurs, verhuurders, huurder/gebruiker
Categorie 6 en 7: gebouweigenaren, installateurs

[1] Bijvoorbeeld nieuwe systemen voor ruimteverwarming, ruimtekoeling, ventilatie, warm tapwater of ingebouwde verlichting (die laatste twee alleen bij utiliteitsgebouwen).
[2] Bijvoorbeeld: verwarmingsketel, warmtepomp, centrale airco, centrale ventilatie-unit, warmwatertoestel, afleverset warmtelevering
[3] Bijvoorbeeld: radiatoren, ventilatieconvectoren.
[4] Bijvoorbeeld een thermostatische radiatorknop, een kamerthermostaat, een thermostaat van een ventilatorconvector of gebouwautomatiserings- en -controlesystemen die de temperatuur kunnen reguleren per verblijfsruimte of verblijfsgebied.
[5] Bijvoorbeeld cv-ketel of warmtepomp.
[6] Het kan gaan om zelfstandige systemen, of systemen gecombineerd met ventilatie. Alleen het verwarmings- en koelvermogen telt; het vermogen van het ventilatiesysteem wordt niet meegeteld.
[7] Bij ingrijpende renovatie geldt de verplichting alleen als de kosten van aanleg niet meer dan 7% bedragen van de kosten van de ingrijpende renovatie.

Image source: epbd-eisen-aan-gebouwen.pdf (rvo.nl)

Why a smart building? – societal challenges

Although making a building smarter seems the most important measure (making it a 100-billion-dollar market in 2024), 70% of the Smart Building initiatives fail!

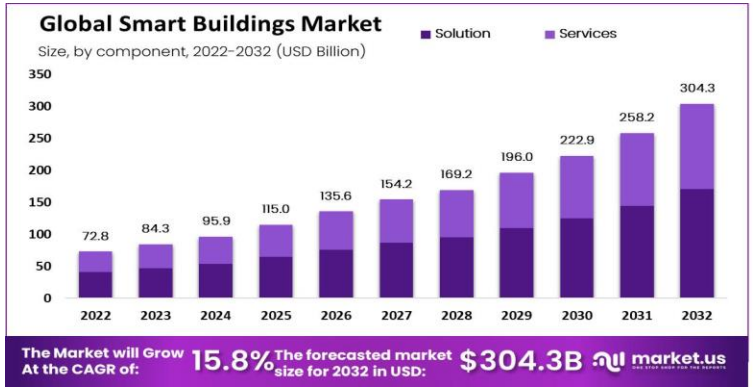
This makes a smart building more of a hype than an effective measure.

For that reason the industry is in need for a clear practical roadmap for achieving asset management goals through data-driven building solutions

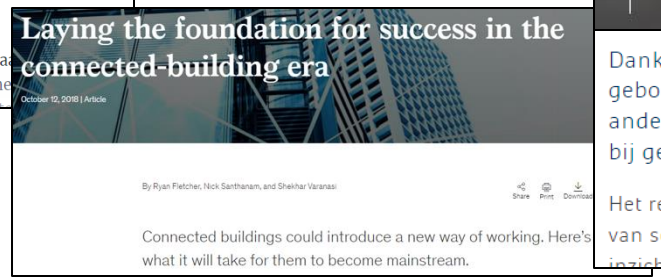
70% (€70 billion last year) of the Smart Building Initiatives fail!

Digital Transformation Is Not About Technology

by Behnam Tabrizi, Ed Lam, Kirk Girard, and Vernon Irvin



Smart buildings is a hype!



Why a smart building? – societal challenges

For these reasons, the B4B-consortium partners combined both theoretical and practical knowledge into an overarching roadmap presented in the following pages. This roadmap illustrates in a step-by-step process, how building owners, asset and facility managers and other actors in the smart building value chain, could start their path towards data-driven ‘smart’ solutions for operational optimalization.

Roadmap for leveraging Smart Buildings

A practical roadmap for achieving asset management goals through data-driven building solutions

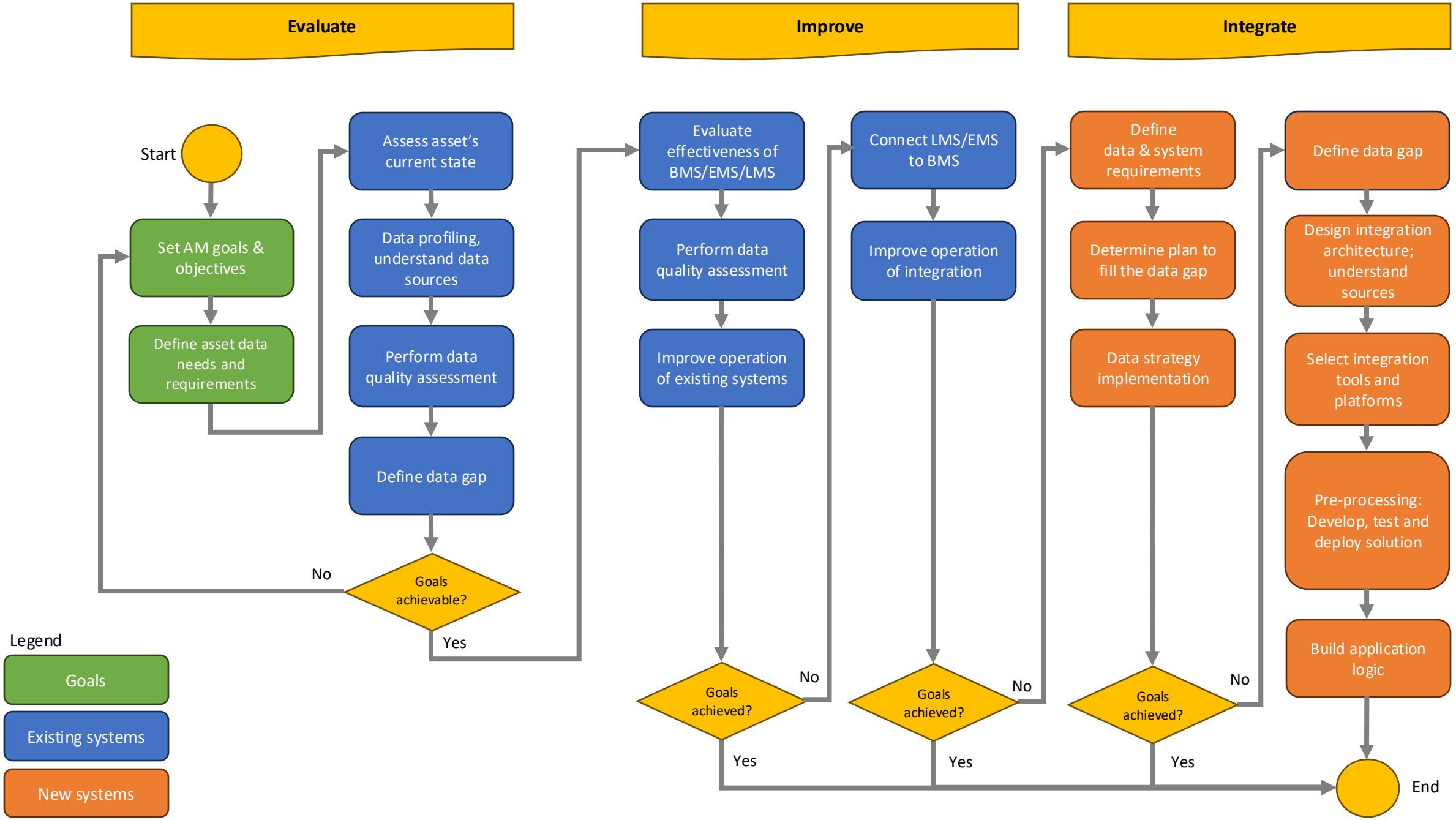
Goal of this handbook

The goal of this handbook is to:

1. create awareness about the current challenges in the industry and how they can be overcome with both high-tech and low-tech solutions;

2. illustrate that a smart building is a tool and not a goal in itself to achieve a (set of) predefined asset management goal(s);

3. provide the different stakeholders in the smart building value chain with a practical roadmap for achieving asset management goals through data-driven solutions, such as data integration.


Evaluate
Improve
Integrate
Start
Set AM goals & objectives
Define asset data needs and requirements
Assess asset's current state
Data profiling, understand data sources
Perform data quality assessment
Define data gap
Goals achievable?
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Yes
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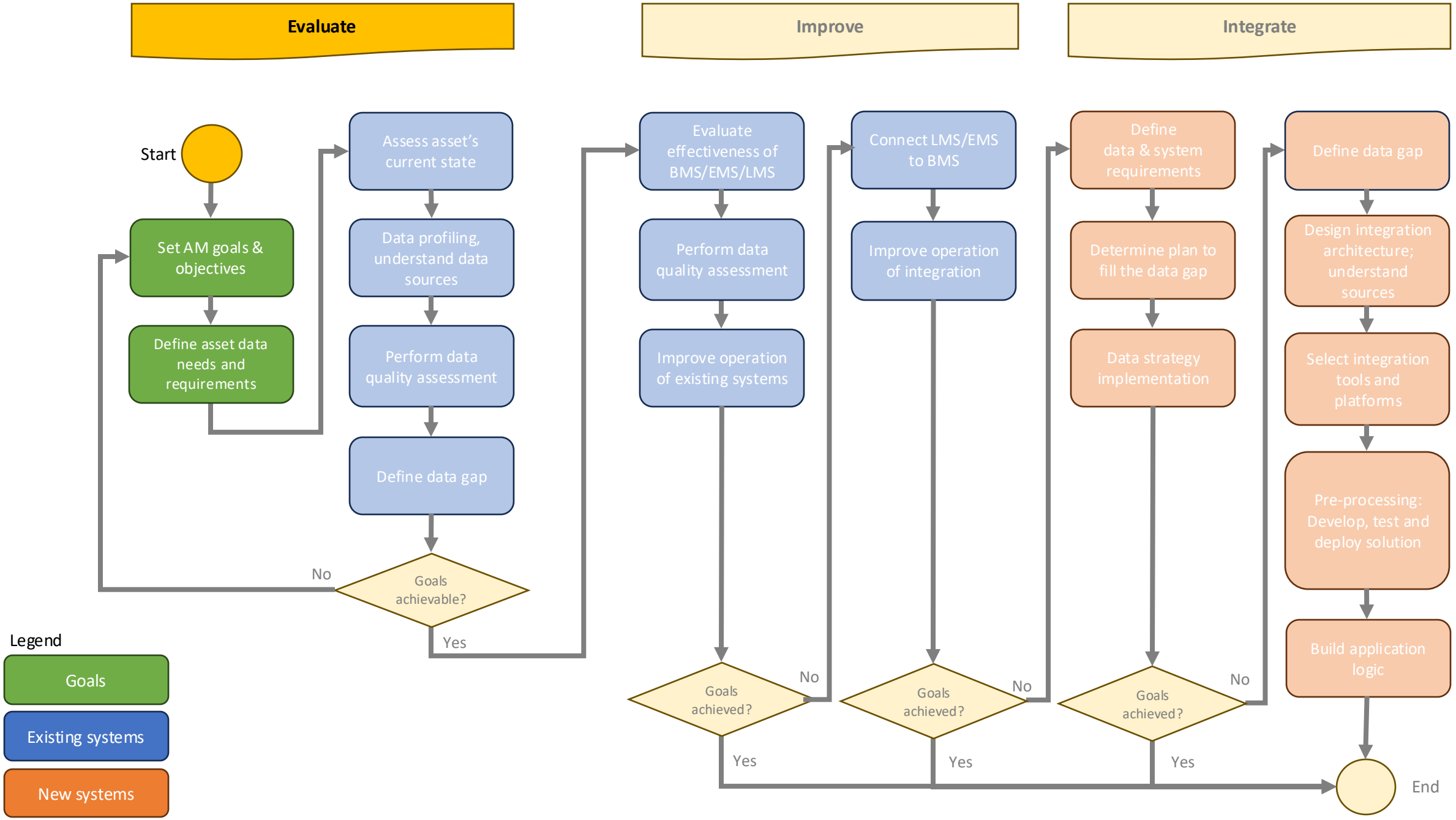
Perform data quality assessment
Improve operation of existing systems
Goals achieved?
No
Yes
Connect LMS/EMS to BMS
Improve operation of integration
Goals achieved?
No
Yes
Define data & system requirements
Determine plan to fill the data gap
Data strategy implementation
Goals achieved?
No
Yes
Define data gap
Design integration architecture; understand sources
Select integration tools and platforms
Pre-processing: Develop, test and deploy solution
Build application logic
End
Legend
Goals
Existing systems
New systems

Stakeholder reading guide

The steps described in this roadmap cover various aspects in the process of optimizing a building or transforming it into a smart building. Many different stakeholders are involved throughout and therefore it is inevitable that the content would not appeal at an equal level to all. This reading guide can help stakeholders who would identify themselves in one of the five columns below choose the sections might want to focus on as part of their roles and responsibilities in the smart building transformation.

	Academics & researchers	Product developers & consultants (Services & products)	Real estate owners (Strategic)	Building- & facility managers (Tactical)	Installers & technicians (Operational)
 Complex / high tech		**Integrate**		**Integrate**	
 Normal / mid-level	**Integrate**	**Improve**	**Improve**	**Improve**	**Improve**
 Simple / low tech			**Evaluate**	**Evaluate**	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Evaluate

Set your goals

Set AM goals & objectives — ISO 55000

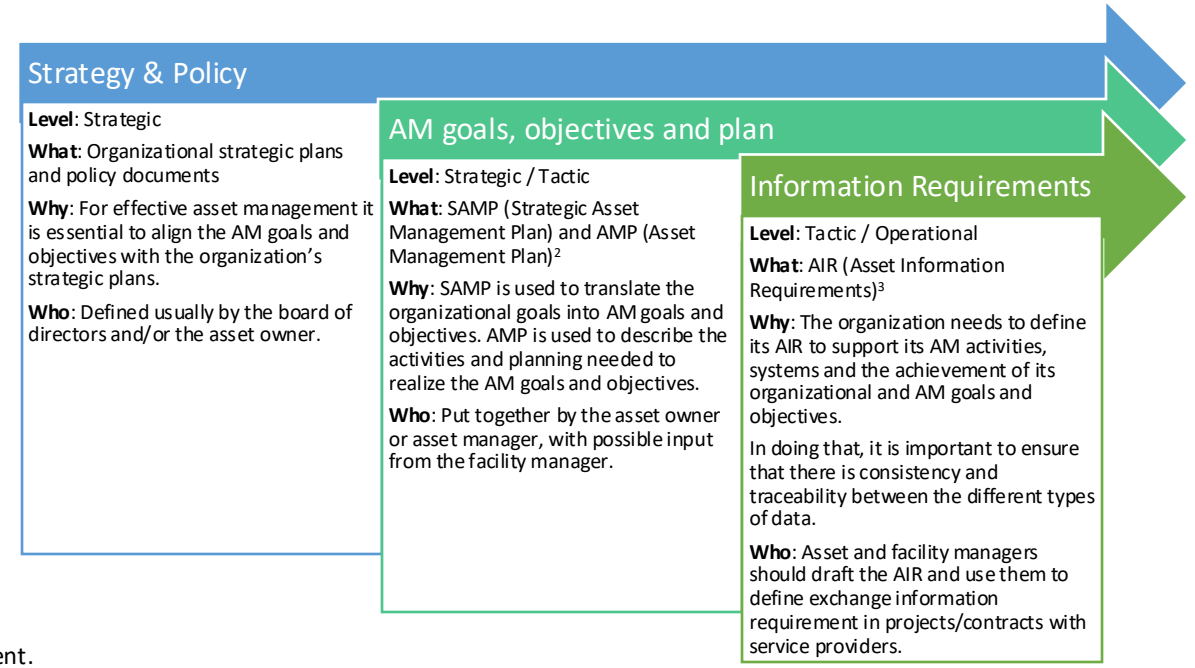
Define asset data needs and requirements — ISO 55001, ISO 19650-3

Smart buildings carry the potential for realizing high value through the collection and analysis of data from various heterogeneous data sources, such as building management systems, sensors and IoT devices. Furthermore, these data sources could be integrated for various purposes to maximize the smart building's potential value.

Asset Management (AM) describes the coordinated processes and activities performed by an organisation to realize value from their assets. What that value is depends on the nature of the organization, its specific objectives and the needs and expectations of its stakeholders.[1]

It is generally considered **good practice** to utilize the guidelines described in the **relevant standards** throughout the process.

To realize the value from their assets, organizations need to have clear organizational and AM goals and objectives. On one hand, they should be derived from the organization's strategy, defined on board level. On the other, they form the starting point for all AM activities and the subsequently the supporting information requirements.



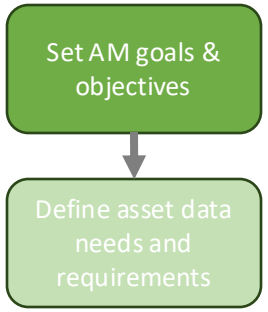
[1] ISO 55000:2014 - Asset management — Overview, principles and terminology

[2] For more information on the content of SAMP and AMP please refer to the ISO 55000 series on Asset Management.

[3] For more information on the content of the AIR, please refer to ISO 55001 and ISO 19650-3 standards.

Evaluate

Set AM goals & objectives



What does this step mean?

Setting up AM goals is a direct result of an organization's vision and strategy and needs to be in place in order to gain insight into the organization and the envisioned value that it aims to gain from its assets. The SAMP (Strategic Asset Management Plan) is a document on strategic level, which translates the organizational goals into asset management goals. The goals and objectives should ideally be formulated in a SMART[1] way as to ensure their adoption in the AM plans and to allow for future evaluation and possible expansion through monitoring KPI's[2].

Why do we need it?

Before an asset owner commences activities to leverage the potential of smart buildings through data integration (or through different means), they should have their asset management goals and objectives clearly defined. This would help guide the follow-up activities, reducing redundancies and costly interventions that would otherwise not contribute to reaching the organization's goals. In addition, it is necessary to define the information requirements for the asset, which is described in the next step.

What are conditions and requirements for its execution?

Setting up organizational goals is a direct result of an organization's asset management vision and strategy. These need to be in place before the goals and objectives can be defined. Then, as an organization begins to set up its goals and objectives they need to consider the following questions:

- Are there already internal vision, mission, strategies or policies that can help determine your goals?
- How does the organization create value out of its assets and will that change in the future?
- What external policies or regulations are there that may impact its goals?
- Are there any financial constraints?
- What are the needs and expectations of the organization and its stakeholders?

Who needs to do it?

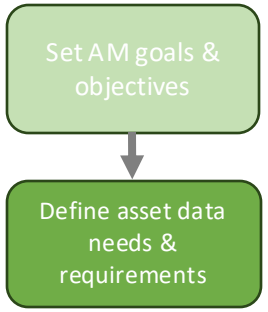
On a strategic level the (mandated) asset owner needs to formulate the asset management goals and objectives in the SAMP. On a tactical level the asset manager (with possible input from the facility manager) needs to translate these goals into actionable plan, the AMP.

[1] They need to be Specific, Measurable, Attainable, Relevant and Time-bound, see also: How to Write SMART Goals (With Examples) - Success in Depth

[2] KPI's, or Key Performance Indicators can be used to track progress towards the AM goals. KPI's should also be formulated in a SMART way.

Evaluate

Define asset data needs & requirements

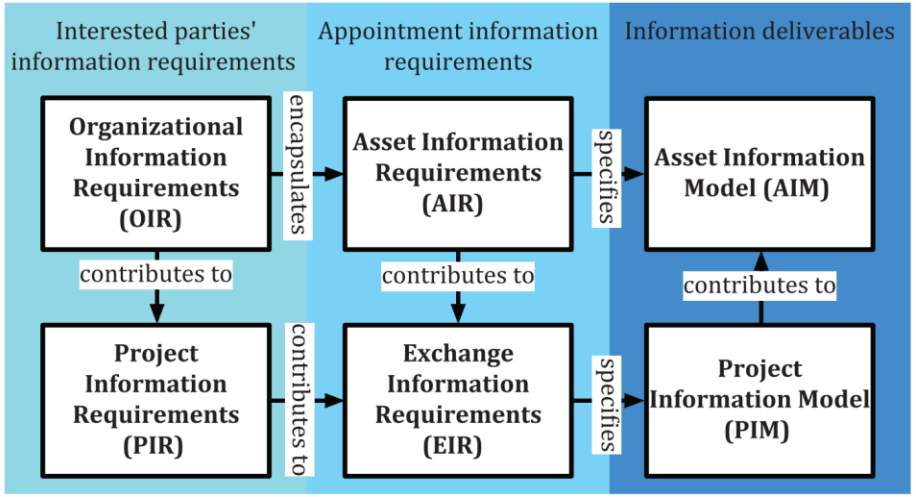


What does this step mean?
The asset information requirements (AIR) include but are not limited to:
- attribute and quality requirements (such as spatial data or unique identifiers),
- the how and when of data collection, analysis and evaluation,
- information management process specification (for example for the collection, validation exchange and maintenance of asset data),
- alignment of terminology.

Why do we need it?
The asset information requirements need to be defined in order to support the activities that fall under asset management. This is necessary for achieving the AM goals and objectives. The AIR is drafted in order to give input for the exchange information requirements (EIR) in projects/contracts with service providers.

What are conditions and requirements for its execution?
The following topics need to be considered before proceeding.
- the purpose for asset information management, such as described in the AMP,
- the ownership of the assets and the information associated with them,
- other roles and responsibilities for the information management of asset data.

Who needs to do it?
On a tactical and operational level, the asset manager should translate the asset management goals and objectives into a concrete plan with design, maintenance and information requirements for its execution. The AIR is drafted by asset and facility managers.



The different types of information requirements and information models as described and elaborated on further in the ISO 19650 series.
Image source: ISO 19650-1:2018 - Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 1: Concepts and principles

Evaluate

Example: SRI

Set AM goals & objectives

Define asset data needs and requirements

not a SMART goal
Have a smart-ready building

versus

a SMART goal
Achieve SRI label class 'A' with focus on energy flexibility by December 2025

The Smart Readiness Indicator (SRI) is a key initiative developed by the European Commission to promote the integration of smart technologies in buildings while standardizing the evaluation of smart buildings. It is essentially an assessment tool that evaluates how well buildings can adapt to their occupants' needs, enhance their energy efficiency, and maintain energy flexibility through smart building systems. Buildings are assessed based on various criteria such as energy management, comfort, health and wellbeing, and maintenance. Each criterion is scored to give an overall SRI rating [1].

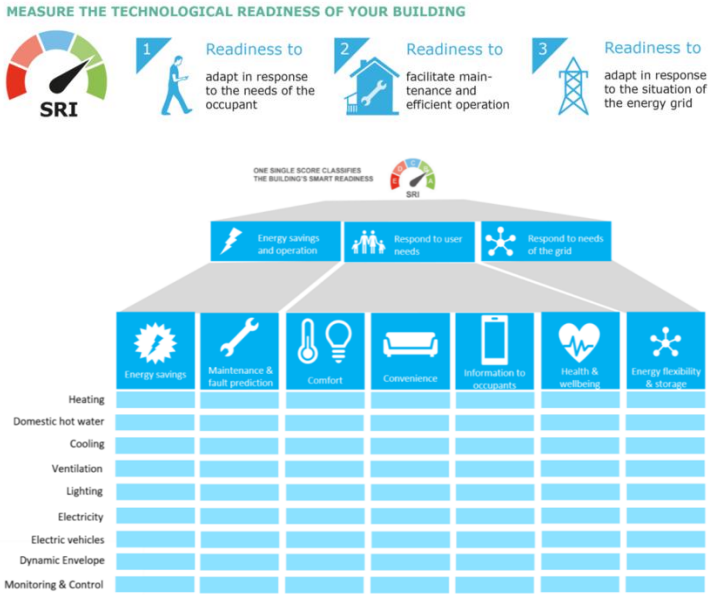
The SRI is part of the EU's broader policy framework on energy performance in buildings. It is defined in the new Energy Performance of Buildings Directive, EPBD (EU) 2024/1275 [2]:

"The smart readiness indicator should be used to measure the capacity of buildings to use information and communication technologies and electronic systems to adapt the operation of buildings to the needs of the occupants and the grid and to improve the energy efficiency and overall performance of building"

Currently (Q2 2024), the SRI is being implemented on a voluntary basis among the EU member states but it has the potential for becoming mandatory in the future as part of national building regulations.

Its development and improvement is progressing through pilot projects in 8 European countries[3], standardization efforts, and stakeholder engagement and feedback [4].

The SRI provides valuable information to building owners, occupants, investors, and policymakers, helping them make informed decisions about investments in smart technologies.



Where to start?

There are currently various software packages developed that can perform this assessment [5].

Since implementation of the SRI might differ from country to country it is important to use a tool or software implementation for a smart building assessment that is aligned with your country's rules and regulations.

The assessment can be done with or without the involvement of external consultants and ideally it should give an indication of where the building stands in relation to the AM ambitions. This information can then be used to draft a gap analysis and a plan of approach for reaching the desired "smart readiness" level.

[1] Smart readiness indicator - European Commission (europa.eu)
[2] Directive - EU - 2024/1275 - EN - EUR-Lex (europa.eu)
[3] For more detailed information on the SRI, please refer to: Contact support (europa.eu)
[4] If you're interested in the SRI test projects please visit: Join our community - Smartbuilt4eu
[5] SRI implementation tools (europa.eu)

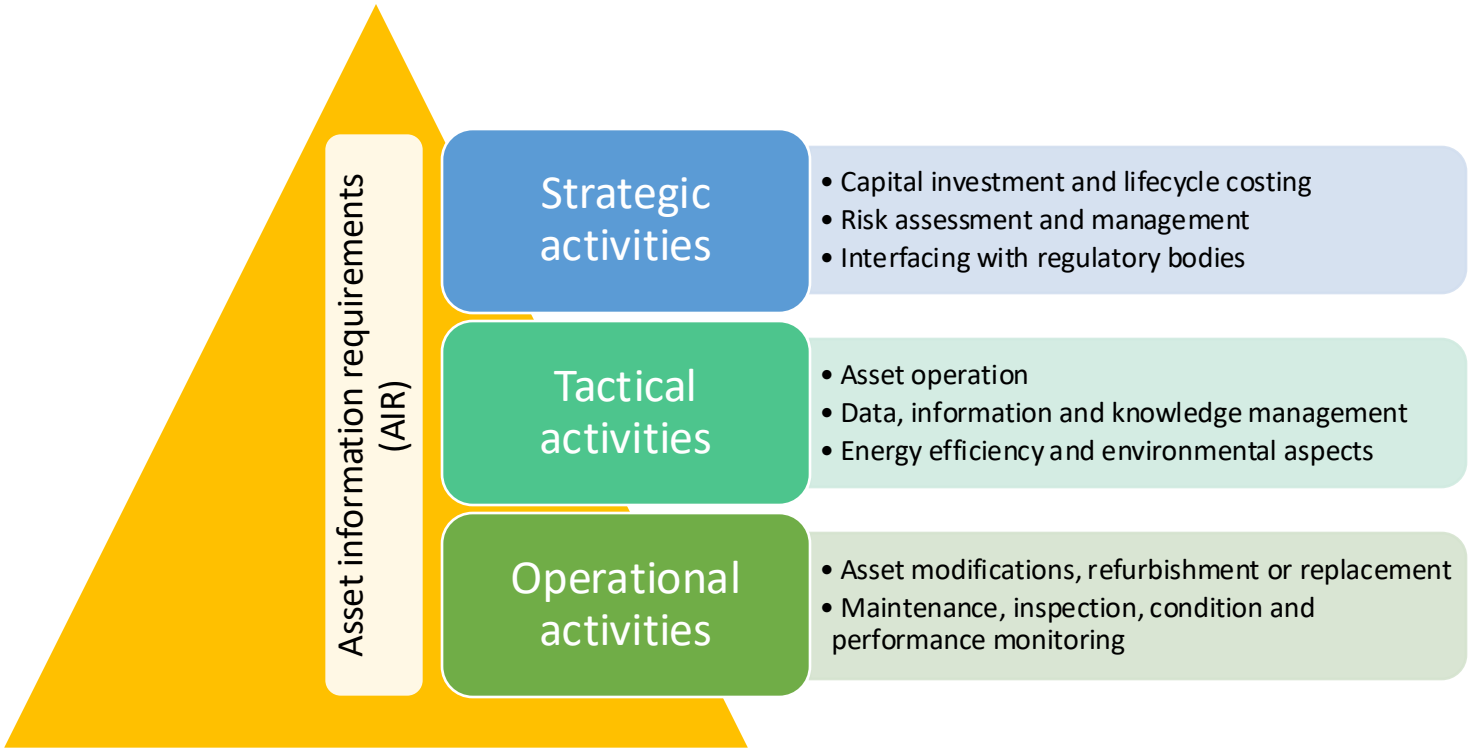
Evaluate

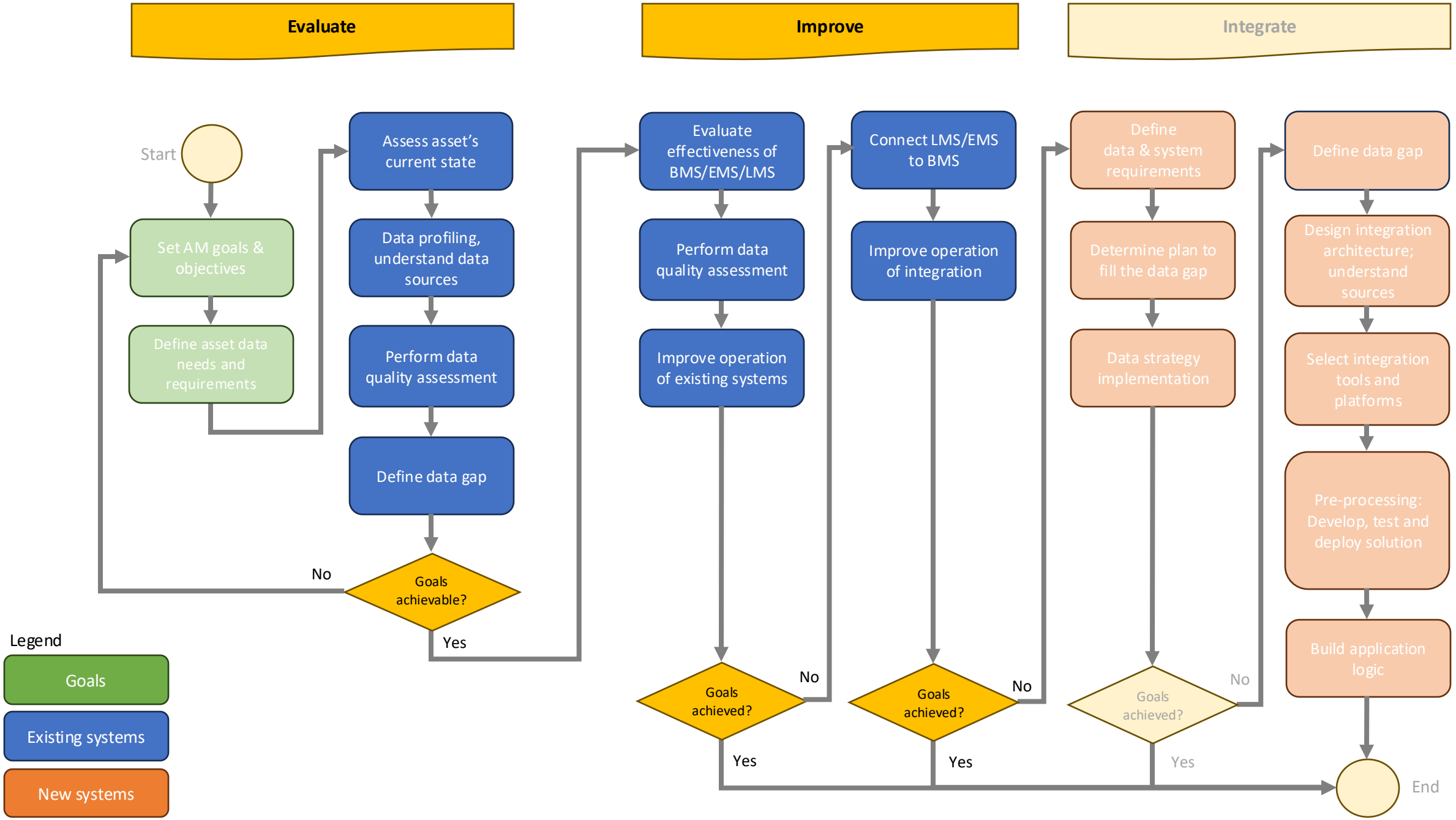
Define asset data needs & requirements

Set AM goals & objectives

Define asset data needs & requirements

The asset information requirements (AIR) are intended to support the strategic, tactical and operational (asset and facility management) activities of the organization. They serve as a backbone and guideline for future prioritized activities and the drafting of execution plans that help the organization reach its objectives.

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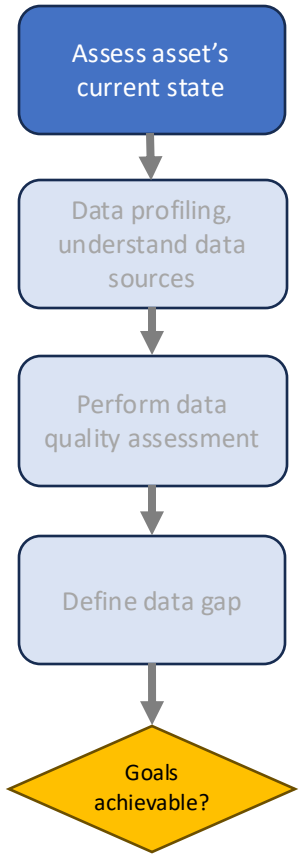
Goals achievable?
No
Yes
Evaluate effectiveness of BMS/EMS/LMS
Perform data quality assessment
Improve operation of existing systems
Goals achieved?
No
Yes
Connect LMS/EMS to BMS
Improve operation of integration
Goals achieved?
No
Yes
Define data & system requirements
Determine plan to fill the data gap
Data strategy implementation
Goals achieved?
No
Yes
Define data gap
Design integration architecture; understand sources
Select integration tools and platforms
Pre-processing: Develop, test and deploy solution
Build application logic
End
Legend
Goals
Existing systems
New systems

Evaluate

Assess asset's state



What do we mean with this step?

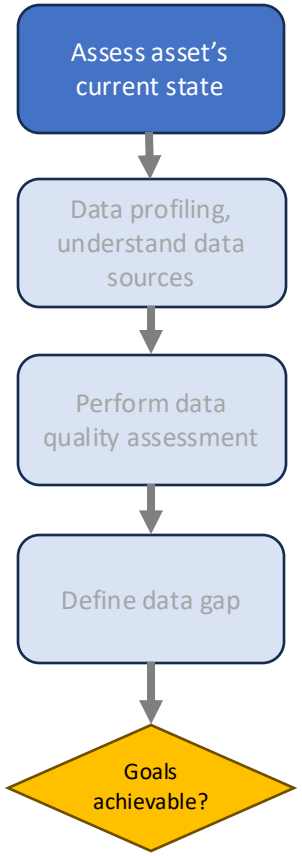
- In this step, it is necessary to determine which systems the asset possesses that are capable of potentially unlocking useful data. And whether the systems are available which are needed to fulfil the goals set in the previous step. Often, we recognize the following systems: the Building Management System (BMS), an Energy Management System (EMS), a Safety Management System (SMS), a Light Management System (LMS), or specific sensors that provide insights.
  The main objective is to form a broad overview of assets and the potential data sources that can be utilized to achieve the set goal(s).

Why do we need it?

- It is important because in this step we develop the framework upon we will build our data integration strategy.

Evaluate

Assess asset's state



What are conditions and requirements for its execution?

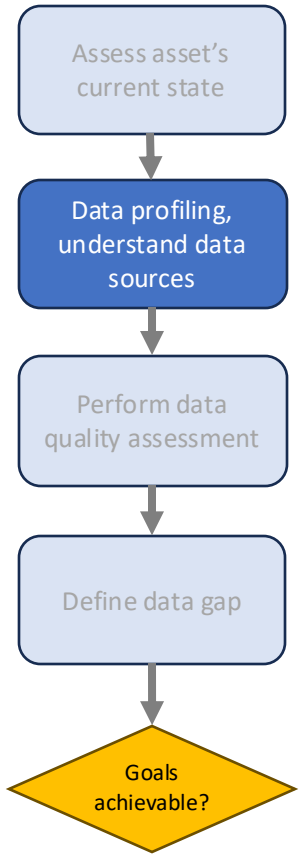
- To make sure this step is executed successfully you need all the information that is available regarding the systems in the asset. This can be a BIM model, CAD-drawings, asset lists, detailed diagrams and schematics used in the design and construction of the asset etc.
- It is important that it is clear 'who' is responsible for this step (often many different stakeholders are having bits of information and therefore the information is everywhere and nowhere).
- The end result should be a list of assets and the (potential) data they (can) produce.

Who needs to do it?

- The information manager (which should be selected by the owner/asset manager responsible for the asset).
- Although not responsible, the Installers & technicians will have a lot of this information.

Evaluate

Determine available data



What does this step mean?

- In this step we will make a deepening on the framework (the list) we developed in the previous step. Were the previous step was about framing the foundation (determine what assets are there) in this step we make a deep-dive in the available data. So, what data do we have.
- To do so we must find out per asset (which is able to unlock data) what kind of data the asset delivers.

Why do we need it?

- Having the asset which potentially can unlock data is one thing, determining whether there is actual data is another thing.

What are conditions and requirements for its execution?

- In this step it is necessary that we know what the goals are and what the data needs are (defined in step 2). Otherwise, we get lost in a data overload. Therefore, we start with the set goal, and we make the breakdown in assets (previous step) and than into the data. For example, if the goal is to automate Legionella flushing cycles you want to know where the 'water points' are (showers/water taps). See step "assess asset's current state". Then we have to find out whether these assets 'produce' data. Lots of (smart) water points nowadays produce data (use frequency and water temperature). In this step you produce an overview as shown on the picture on the right.

Who needs to do it?

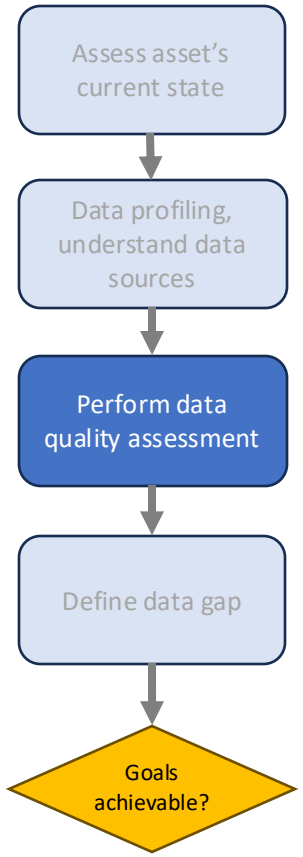
- The information manager (which should be selected by the owner/asset manager responsible for the building).
- Although not responsible, the hard service provider will have a lot of this information.

Goal: automating legionella flushing rounds.

Assets	Management system	Obligation to flush?	Available data	Interval
Toilet A.104	WMS: Appex 230	No	not applicable	not applicable
Toilet A.105	WMS: Appex 231	No	not applicable	not applicable
Toilet A.106	WMS: Appex 232	No	not applicable	not applicable
Shower A.105	WMS: Appex 233	Yes	Temperature of the water	Every 15 min.
Shower A.106	WMS: Appex 234	Yes	Temperature of the water	Every 15 min.
Shower A.107	WMS: Appex 235	No	not applicable	not applicable
Water tap A.105	WMS: Appex 236	Yes	Temperature of the water	Every 15 min.
Water tap A.106	WMS: Appex 237	Yes	Temperature of the water	Every 15 min.
Water tap A.107	WMS: Appex 238	No	not applicable	not applicable

Evaluate

Data quality assessment



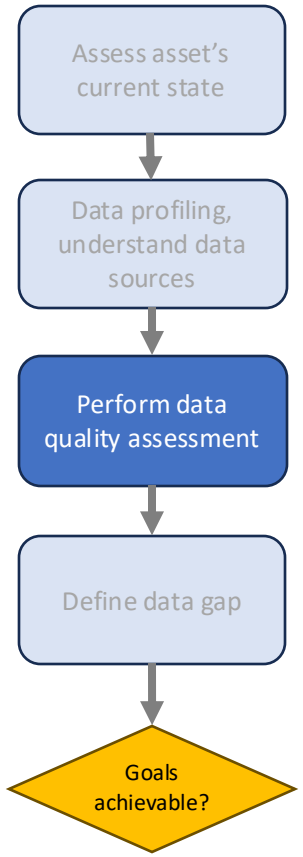
What do we mean with this step?

In this step we will judge whether the quality of the data is good enough to meet your goals. This is a technical step where an expert will look at the following 8 items:

1. Data Validation: Ensure that the data complies with predefined rules and standards. This involves checking the accuracy, format, consistency, and range of the data.
2. Duplicate Data: Identify and remove duplicates in the dataset to prevent the same data from being included multiple times. This can be achieved by sorting the data and identifying duplicate records based on unique identifiers.
3. Missing Values: Check for missing values in the dataset and determine how to handle them. This may involve filling in missing values with averages, medians, or other statistical methods, or choosing to remove records with missing values.
4. Accuracy: Verify the accuracy of the data by taking samples and comparing them to sources of known accuracy. This can be done manually or using automated tools.
5. Consistency: Ensure that the data is consistent across different sources and systems. This involves checking the terminology, units, and codes used to ensure they are uniform.
6. Integrity: Check the integrity of the data by examining relationships between different datasets. This includes verifying references between tables and identifying inconsistent or incorrect relationships.
7. Timestamps and Version Numbers: Keep track of timestamps and version numbers to monitor changes in the dataset and ensure the timeliness and completeness of the data.
8. Data Profiling: Utilize data profiling tools to analyze the structure, patterns, and statistics of the data and identify any anomalies or deviation

Evaluate

Data quality assessment



Why do we need it?

- Having the data is one thing but determining whether the quality of the data is good enough is a different thing.

What are conditions and requirements for its execution?

- To execute this step, it is important that the previous steps are executed properly, meaning that we need to know 1) what the exact goal is, 2) whether we have the right assets which can produce the needed data and 3) whether the data is there.
- A method on which to determine whether the quality is good enough. There are many ways/methods to assess the quality currently (2024) these are some of the top performing tools for that :

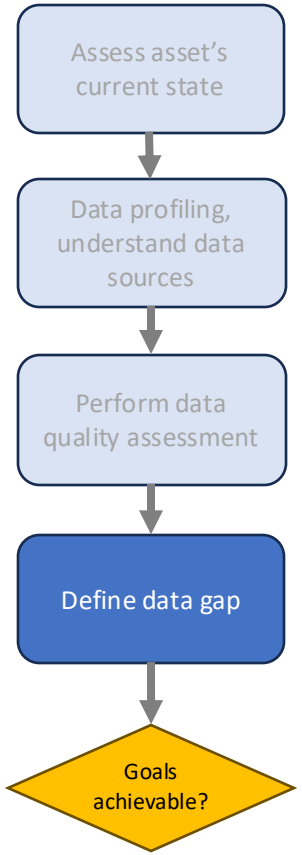
IBM InfoSphere Information Analyzer: This is a powerful tool for data profiling and quality control used to analyze the structure, content, and quality of data.
Informatica Data Quality: This tool offers comprehensive capabilities for data profiling, including analyzing missing values, unique values, data patterns, and statistical distributions.
Trifacta Wrangler: Trifacta Wrangler is a self-service data preparation tool that allows users to easily profile and transform data.
OpenRefine: OpenRefine is an open-source tool for data cleaning and transformation, which can also be used for data profiling.

Who needs to do it?

- The information manager (which should be selected by the owner/asset manager responsible for the building).

Evaluate

Define data gap



What do we mean with this step?

- In this step we identify the data we do not have but which we need to fulfill our goals. So we know what additional data has to be added.

Why do we need it?

- This step is important to determine what additional assets (and data) are necessary. If this gap is too big the costs to fulfill your goals will be high, which will maybe result in a negative business case.

What are conditions and requirements for its execution?

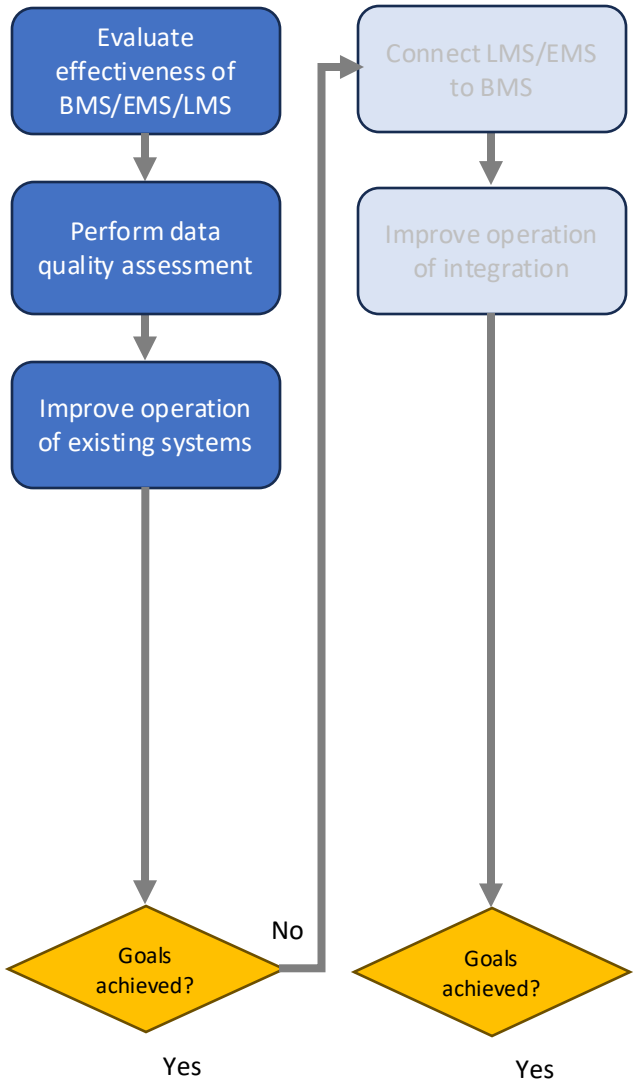
- Knowing what data you need to fulfill the goal and to know what data we have available.

Who needs to do it?

- The information manager (which should be selected by the owner/asset manager responsible for the building).

Improve

Evaluate effectiveness of BMS/EMS/LMS



What does this step mean?

- This step contains 3 sub-steps, but they all have the same purpose: optimizing the current management systems which are in place to make sure the building is operating properly.
  - Evaluate effectiveness: evaluate whether the current management systems are working as they supposed to
  - Perform an analysis to make sure the data quality is good enough
  - Improve the systems

Why do we need it?

- In the Netherlands, 70% of comfort systems are not operating optimally[1]. A significant reason for this is that the building management systems are not properly configured. This is logical because during the design of a building, specific occupancy and functions are assumed. However, these often change very quickly, resulting in the building not being tailored to the corresponding function and occupancy.
- An analysis of many building management systems in existing buildings reveals that simply by optimizing the BMS (meaning solve the low-hanging fruit like optimizing the clock-times, optimize institutions) will result in an energy saving of approximately between 5% - 20%[2].

What are conditions and requirements for its execution?

- The following steps are important for the execution:
  - Make sure the right skills are in place (to optimize a BMS you need specific skills; these are other skills than optimizing a Light management system).
  - Make sure the functionality of the building is clear. What are the opening times, what are the required performances of the building etc. This will be the input to optimize the management systems.

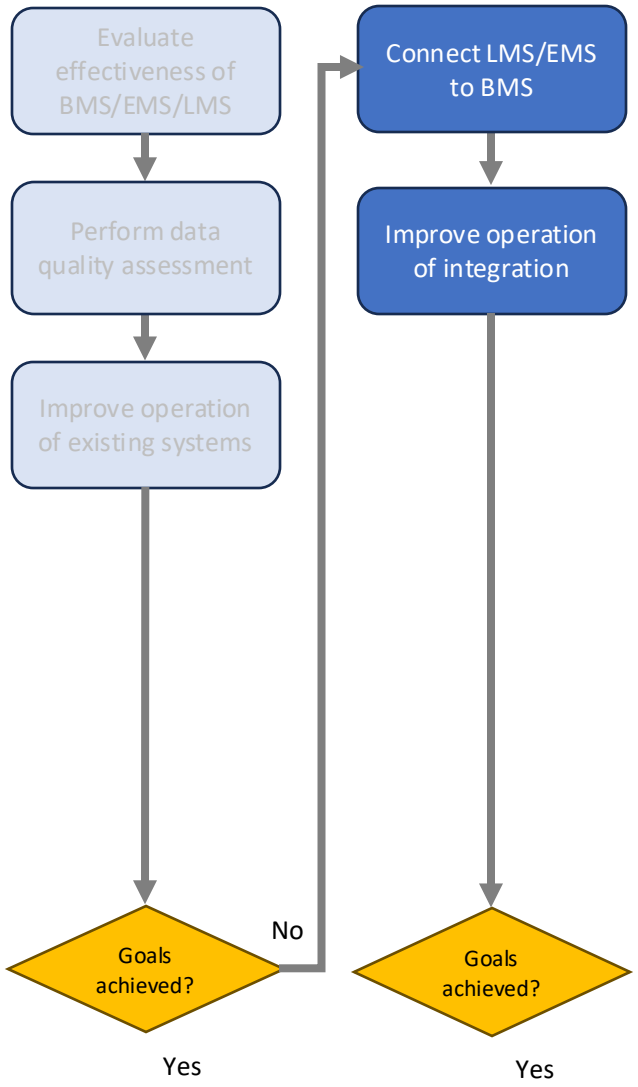
Who needs to do it?

- The hard service provider or the BMS service provider can help you with this step. For specific items (lighting, energy) the specialist needs to be consulted.

[1] 70% van koelinstallaties werkt niet optimaal | (installatietotaal.nl)
[2] Energy Efficiency – Lawrence Berkeley National Laboratory (lbl.gov)

Improve

Connecting assets



What does this step mean?

- A building has many stand-alone operating systems (burglary installation, light, energy etc.). Connecting these existing systems without 'adding' new systems to the building has shown to be a very interesting manner to optimize the building and realize the goal you have.

Why do we need it?

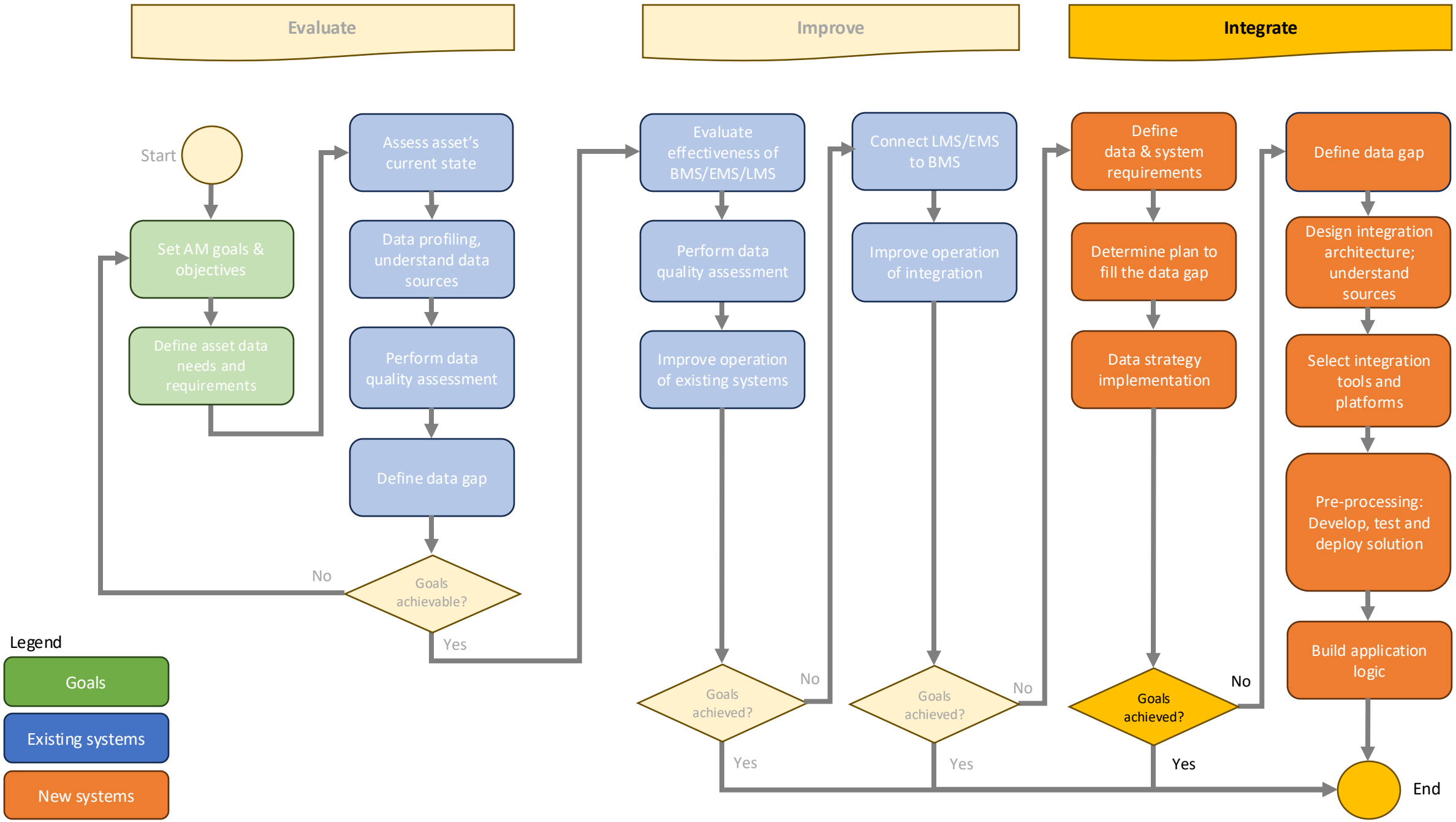
- This step is important because it is a very (cost) effective way to optimize the performance of the building. And therefore, is it a very 'smart and easy' step by improving without bringing any new systems into the building.

What are conditions and requirements for its execution?

- To execute this step, it is important to understand what assets you have and how/why you can combine them. This requires knowledge of the individual assets and what they can achieve combined. There are many specialists (hard service provider is one of them) who knows what combinations will create value.

Who needs to do it?

- The hard service provider or the BMS service provider can help you with this step. For specific items (lighting, energy) the specialist needs to be consulted.

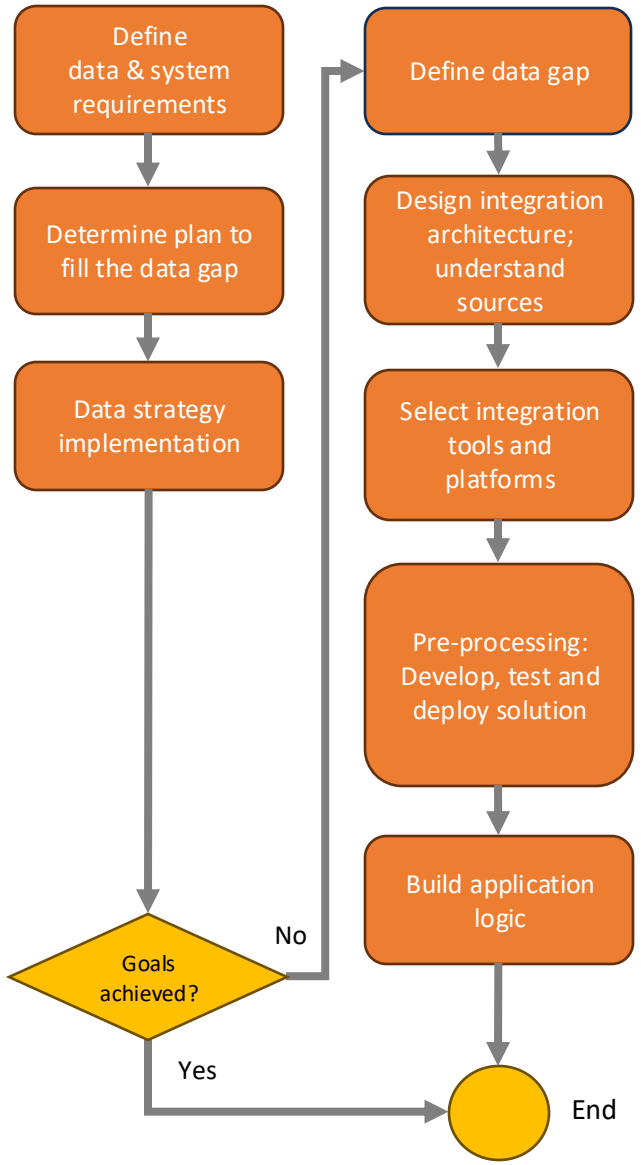

Evaluate
Improve
Integrate
Start
Set AM goals & objectives
Define asset data needs and requirements
Assess asset's current state
Data profiling, understand data sources
Perform data quality assessment
Define data gap
Goals achievable?
No
Yes
Evaluate effectiveness of BMS/EMS/LMS
Perform data quality assessment
Improve operation of existing systems
Goals achieved?
No
Yes
Connect LMS/EMS to BMS
Improve operation of integration
Goals achieved?
No
Yes
Define data & system requirements
Determine plan to fill the data gap
Data strategy implementation
Goals achieved?
No
Yes
Define data gap
Design integration architecture; understand sources
Select integration tools and platforms
Pre-processing: Develop, test and deploy solution
Build application logic
End
Legend
Goals
Existing systems
New systems

New systems

Integrate

When the existing systems don’t suffice, extensions are necessary. This can be done with hardware and/or software. The flow diagram outlines the steps involved in a data strategy process, divided into two main stages: "Extend" and "Integrate.“

The following pages go through each of the steps on the right and describe what the steps entail, what the benefits are and what type of expertise might be required to perform the task.



Extend existing data

Integrate

Extending the existing data can be achieved by replacing existing measurement devices or increasing the number of sensors in a building. Other times, the settings on existing sensors can be altered to increase the measurement frequency. There are three steps to the process:

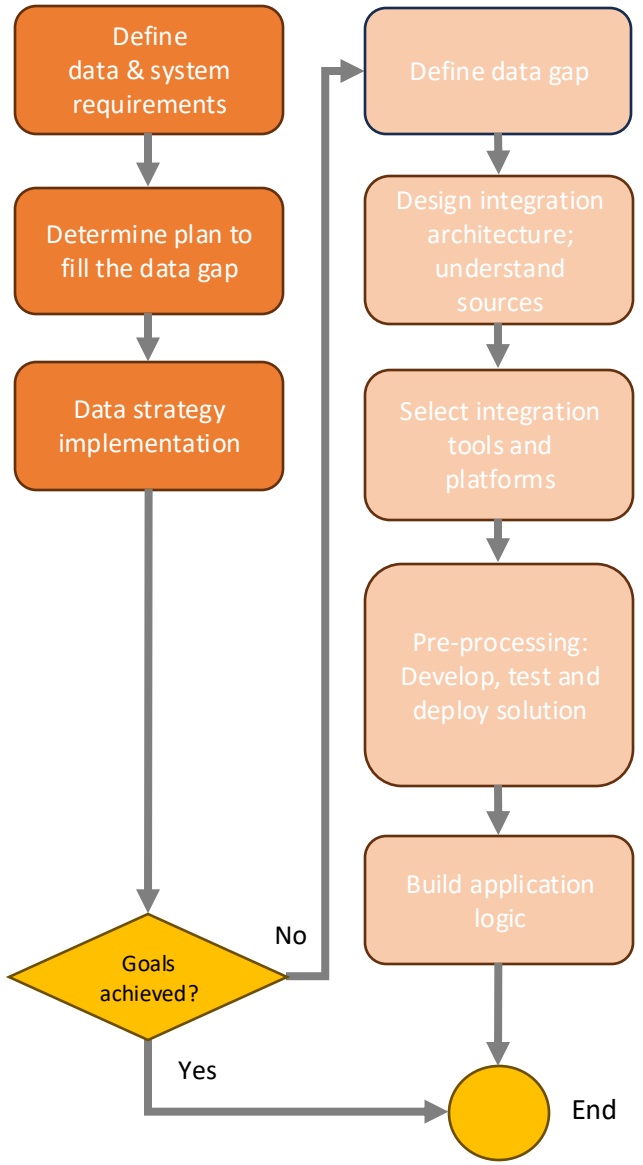
1. Define Data & System Requirements:
Identify and outline the specific data needs and system requirements necessary to reach the AM goals.

2. Determine Plan to Fill the Data Gap:
Develop a detailed plan addressing how to fill any identified gaps in the existing data.

3. Data Strategy Implementation:
Execute the planned strategies to collect and generate the required data.

Goals Achieved?:
- Evaluate if the goals of the data strategy have been met.
- If the goals are achieved, the process ends here.
- If the goals are not achieved, the data strategy implementation does not end with.

Examples:
- It is preferred to know the temperature and flow of the incoming air to the AHU while there is currently no flow sensor installed.
- There are no (digitally) controllable valves for the heating per room. The extension would be to install controllable valves on the heating installation.



Define data & system requirements

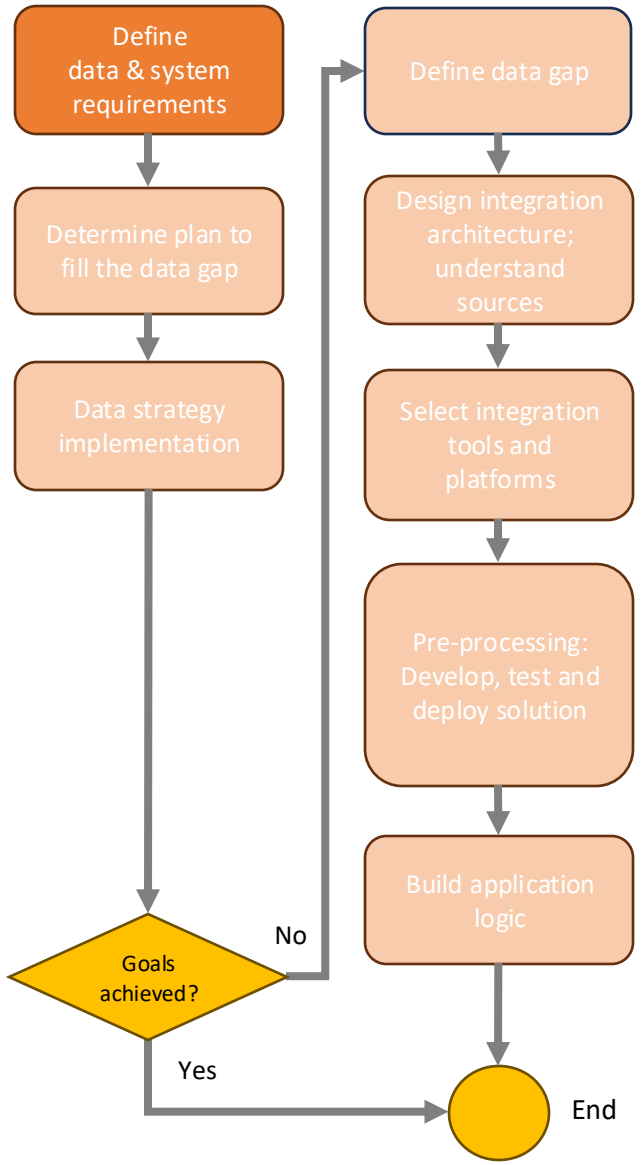
Integrate

What does this step mean?
When extending the gathered data with new sensors, the first objective is to define the requirements. There are specific requirements from the existing system, as well as requirements from the data/sensor itself to have the data gap filled after deploying the new measurement devices. Questions to ask:

- Which type of sensors/actuators need to be installed?
- Which communication protocol do these sensors use?
- What is the measurement frequency?

Why do we need it?
When sensors are installed without looking at the existing systems in the building, it might not be possible to integrate the new sensors. E.g. if the sensors communicate using Modbus, but the existing BMS only supports M-bus, there will be difficulty with the implementation. This is a **system requirement**.
Additionally, if a measurement frequency of one second is required, but the sensor can only measure once every minute, the **data requirements** are not met.

Who needs to do it?
Product developers and consultants, building and facility managers



Install additional monitoring

Integrate

What does this step mean?
The next step is to determine a plan for filling the data gap, while obliging to these requirements.

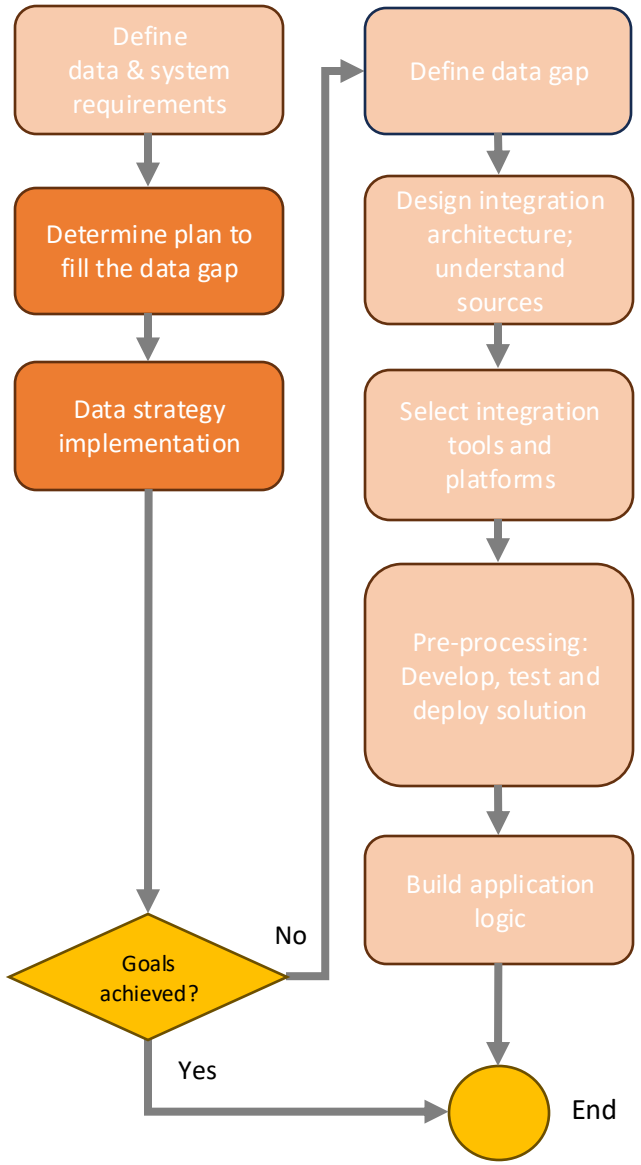
Questions which need to be answered:
- Where do we install these sensors and control valves?
- What is the prioritization of the identified installations?
- What are the costs involved with filling these gaps?

After that, the next step is to implement the data strategy, which is the deployment of the beforementioned plan.

Why do we need it?
Without a plan, the implementation might run out of budget or out of time.

What are conditions and requirements for its execution?
See previous step.

Who needs to do it?
Building- and facility managers, installers

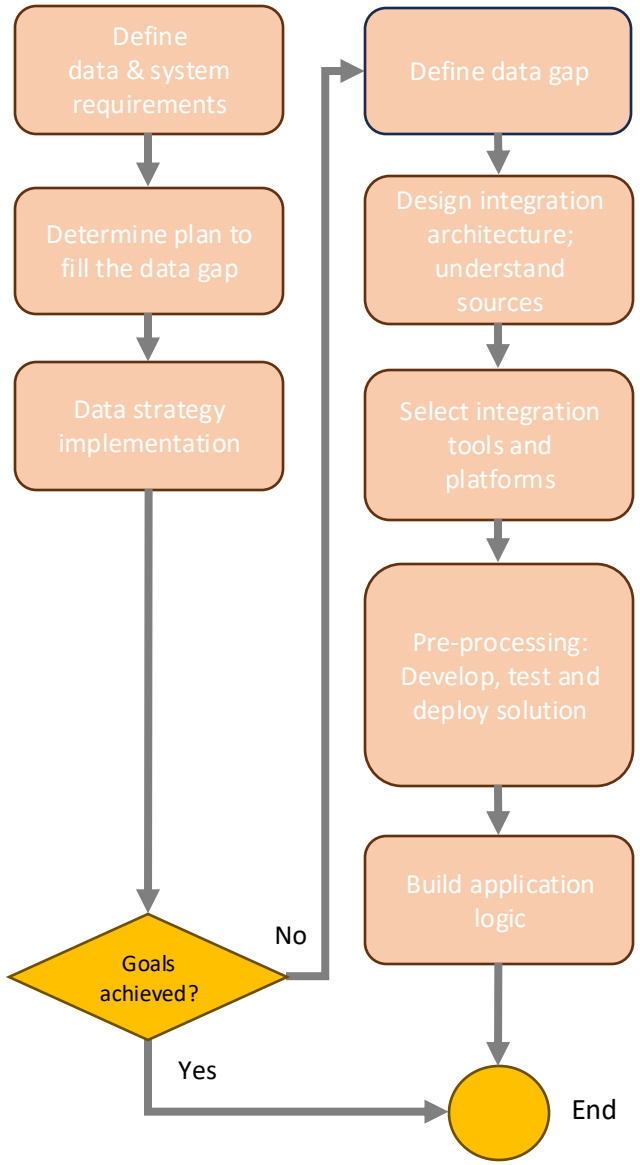


Install additional monitoring

Integrate

It might be that the goals are achieved by installing new sensors. This means that extra steps regarding data integration are not necessary, the journey ends.

Enjoy the improved operation of the building!



Data integration

Integrate

Smart building applications rely on operational and contextual data from various sources and systems:

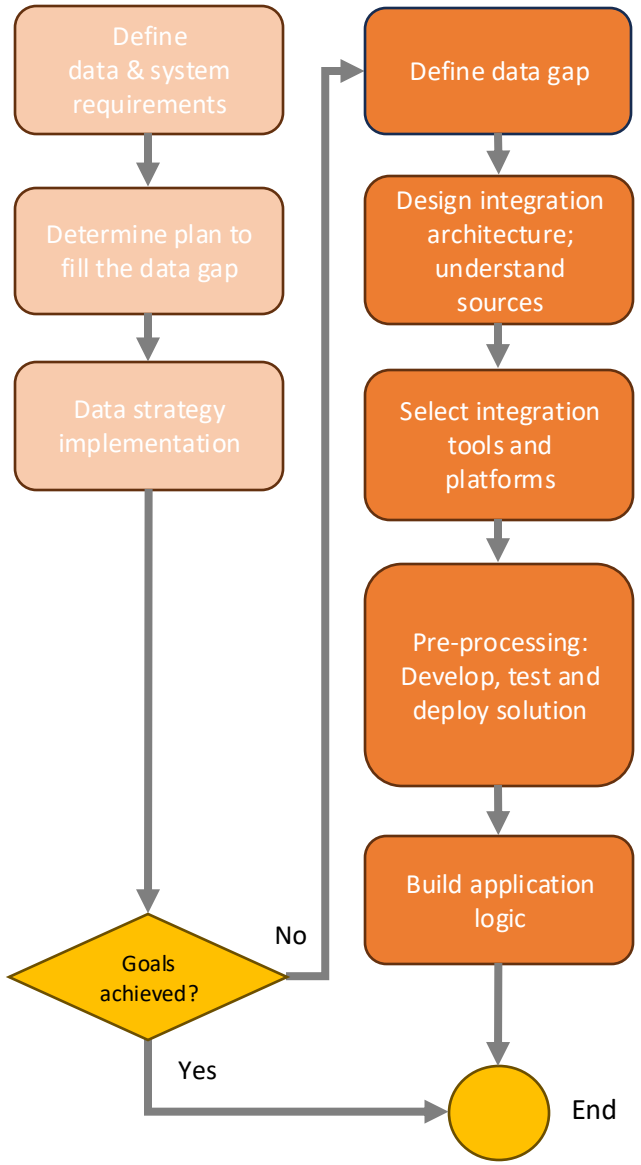
- **time series data** provide operational information for HVAC systems, lighting, alarms, energy meters, weather services, smart devices, etc.
- **contextual building data (linked data)** includes Building Information Models (BIM), technical drawings, Process and Instrumentation Diagrams (P&ID), product databases, etc., which contain information about the configurations and relationships between different systems and their components.

There is little interaction between these islands of data due to their heterogeneity

- They rely on different modelling approaches, languages and protocols
- e.g., there is no straightforward way to integrate a Honeywell BMS system with a BIM model created on Autodesk Revit

Lack of interoperability hinders the research and development of smart building applications. The ability to integrate systems from multiple vendors is a major requirement to understand the energy usage, maintenance, and overall performance of buildings.

Therefore, it is necessary to setup a data infrastructure which allows for more extensive data interactions. These steps are described on the following pages.



Define data gap

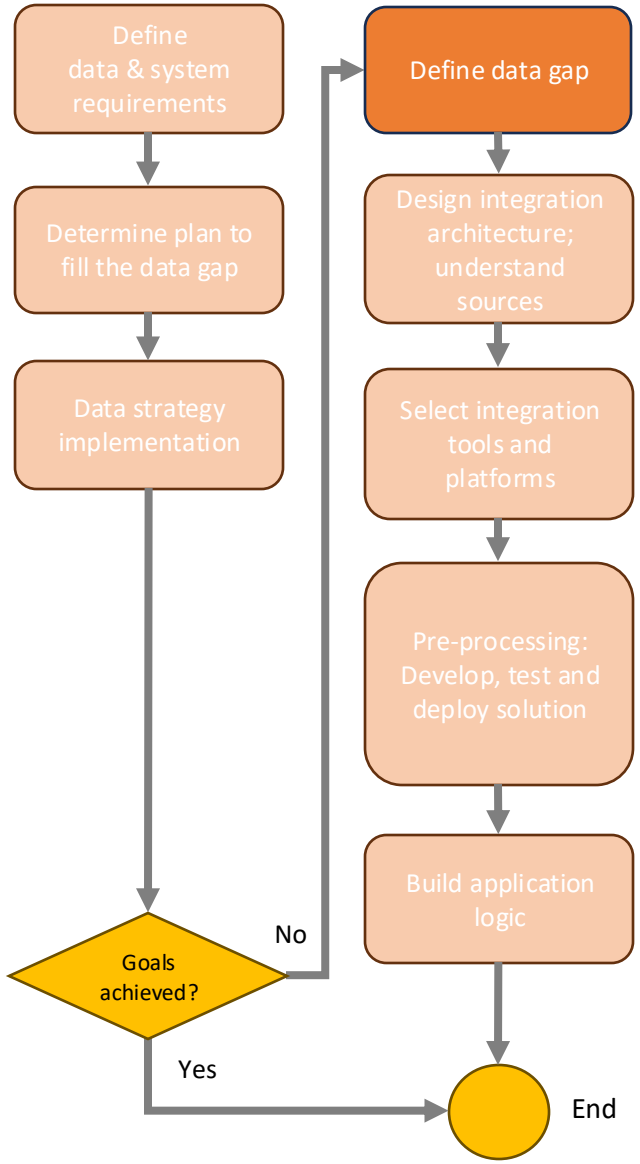
Integrate

What does this step mean?
In this step, it is required to think about the asset management goals and how data/information can be used to achieve these goals.

Why do we need it?
Without taking the time to think about the remaining gaps, there is no end goal to work towards while integrating different types of data.

What are conditions and requirements for its execution?
Knowledge of the existing data streams and asset management goals to be met using data analysis.

Who needs to do it?
Building- and facility managers, installers



Integration architecture

Integrate

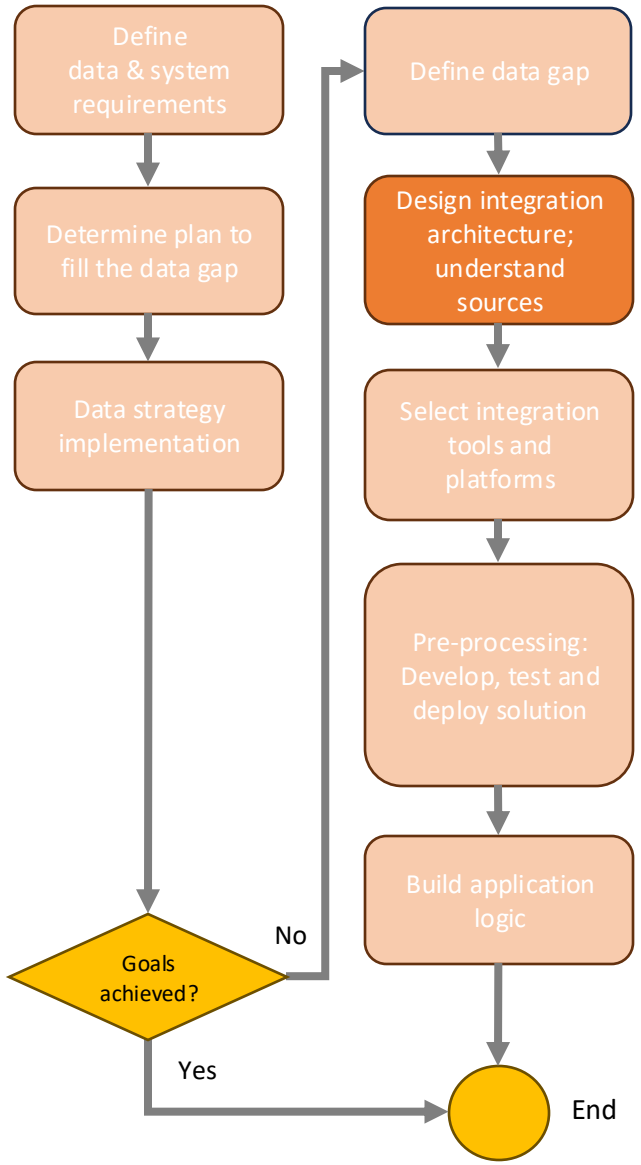
What does this step mean?
Smart buildings need to rely on a well-defined system architecture and Application Programming Interfaces (APIs) that enable both the integration of diverse systems and datasets and the orchestration of various services. Chamari et al. (2023) present a generic reference architecture focusing on data integration and system integration. See the next slide for an illustration.

- Choose an appropriate integration architecture (e.g., centralized, decentralized, hybrid) based on the scale and complexity of the BMS.
- Design data flow diagrams to visualize the movement and transformation of data across systems.

Why do we need it?
Each individual building is unique and path dependency plays a role, so developing a 'one size fits all' system architecture is impossible.

What are conditions and requirements for its execution?
Knowledge of different platforms and communication options to those platforms.

Who needs to do it?
Data(base) engineer, building and facility managers

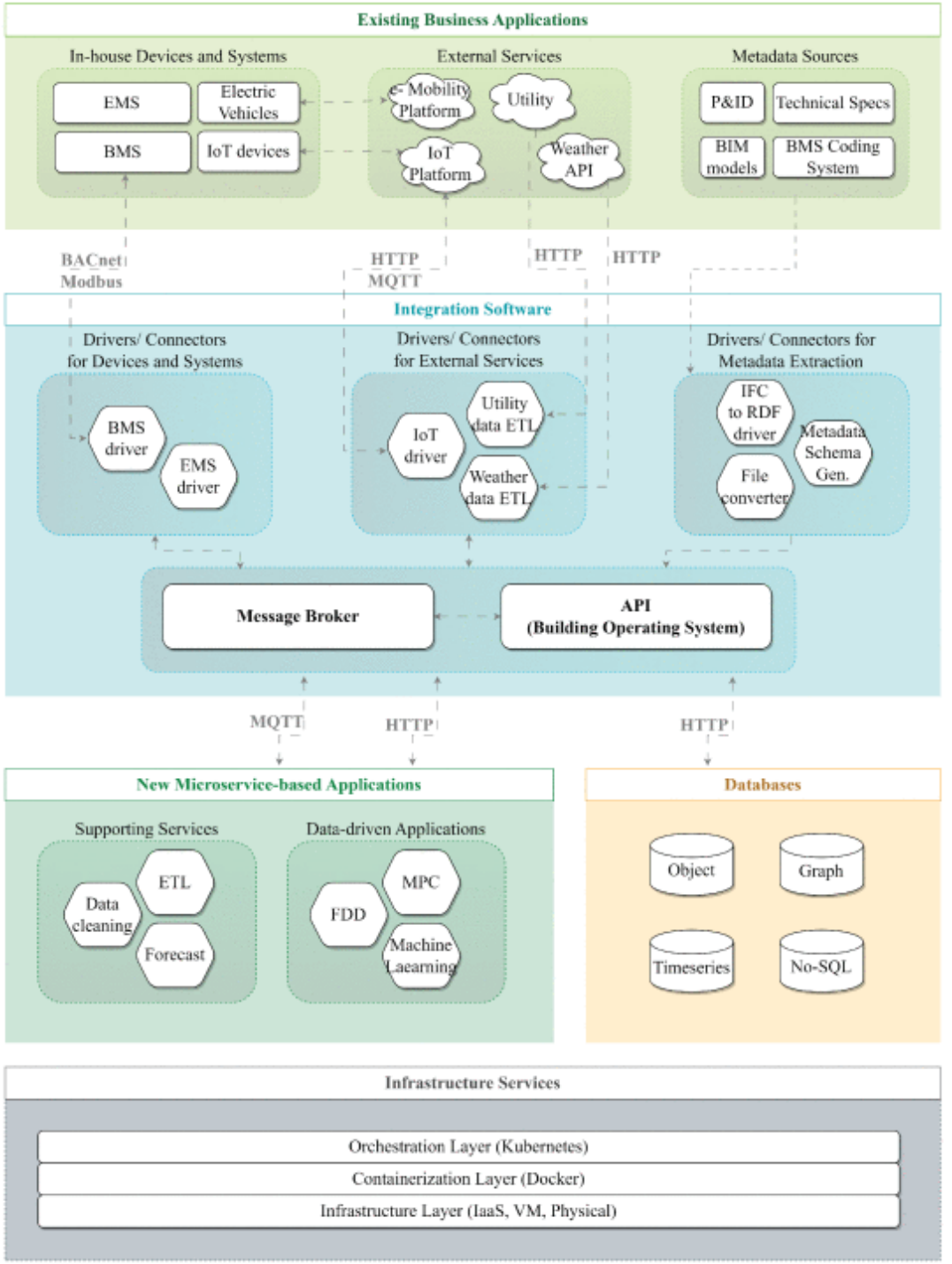


Reference architecture

The focus at this point is on the top half of the reference architecture on the right: The Data Sources Layer has been addressed in the previous steps. The Integration Layer and Data Layer are what we are discussing at this point.

The choice of a message broker, time series database, drivers and metadata database should be guided by the specific requirements of the BMS in terms of scalability, performance, data types, and operational environment. It is also important to consider how these components integrate with each other to create a cohesive data integration ecosystem. We'll discuss these components in the next slides.

The needed building blocks are dependent on the availability and required level of integration. E.g., if there are no IoT devices in the building which rely on Zigbee network with MQTT data sharing, then there is no need for an IoT Driver with MQTT.



Source: L. Chamari, E. Petrova and P. Pauwels, "An End-to-End Implementation of a Service-Oriented Architecture for Data-Driven Smart Buildings," in IEEE Access, vol. 11, pp. 117261-117281, 2023, doi: 10.1109/ACCESS.2023.3325767

Message broker

What does this step mean?
A message broker acts as an intermediary for messaging between different systems or software components.

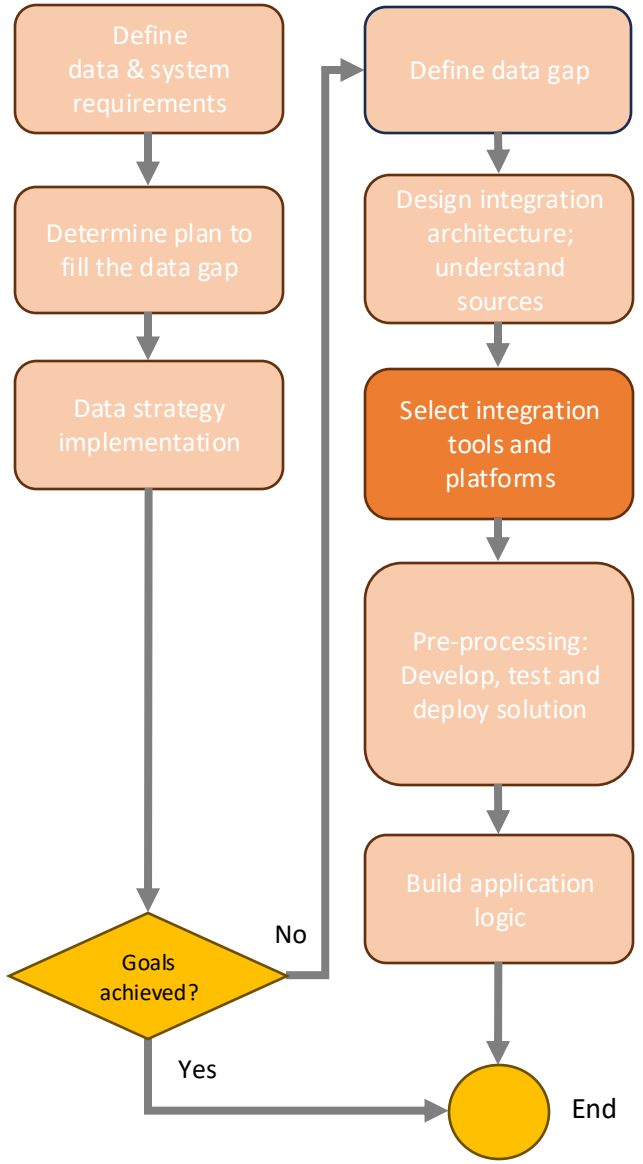
Why do we need it?
It enables asynchronous communication, ensuring that messages are queued, delivered, and received reliably.

What are conditions and requirements for its execution?

- **Scalability**: Ability to handle increasing volumes of messages and connections as the system grows.
- **Performance**: High throughput and low latency, especially crucial in real-time BMS applications.
- **Reliability**: Robust fault tolerance and guaranteed message delivery mechanisms.
- **Protocol Support**: Support for various messaging protocols (e.g., MQTT, AMQP, HTTP).
- **Integration Capabilities**: Ease of integration with existing systems and databases.
- **Security**: Strong security features to protect data in transit.

Who needs to do it?
Data engineer

Examples: RabbitMQ, Apache Kafka, MQTT brokers.



Timeseries database

Integrate

What does this step mean?
A time series database is optimized for handling time-stamped or time-series data, such as sensor readings or log data, which is common in BMS.

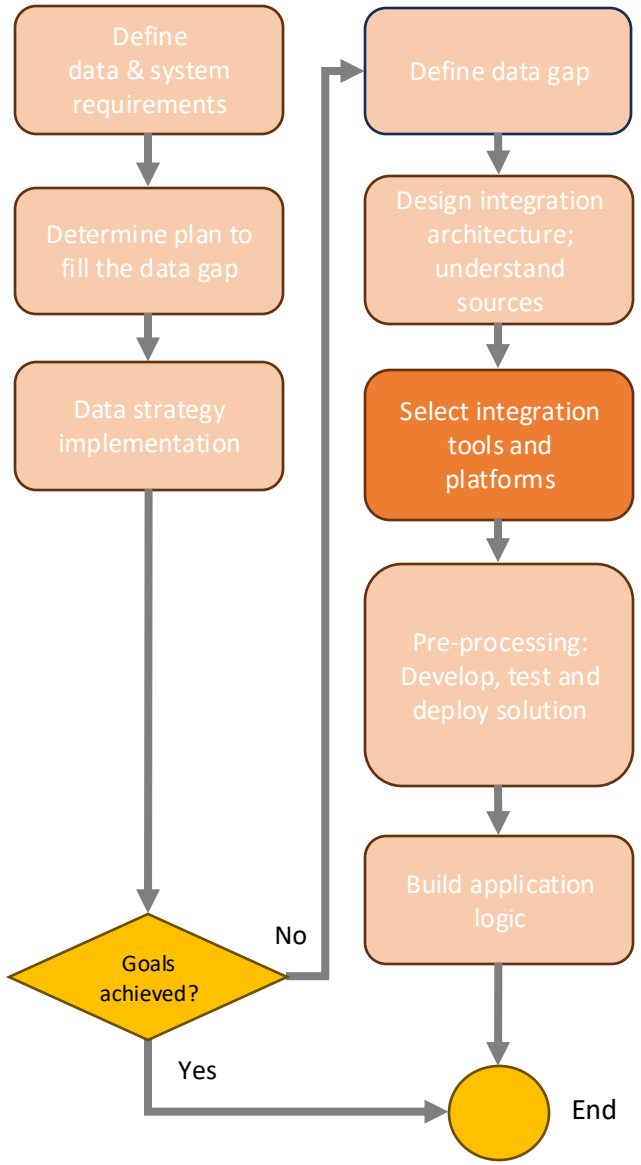
Why do we need it?
The previously mentioned message brokers get expensive when the datasets get larger over time. A timeseries database is ideal for storing information for longer periods of time.

What are conditions and requirements for its execution?

- **Write and Query Performance**: Efficient handling of high-velocity data writes and complex time-based queries.
- **Data Compression and Storage Efficiency**: Effective compression mechanisms to manage large volumes of historical data.
- **Scalability**: Capability to scale out as data volume grows.
- **Data Retention Policies**: Features to manage data retention in line with storage capabilities and compliance requirements.
- **Integration with Analytics Tools**: Compatibility with analytics and visualization tools for data analysis and reporting.
- **Reliability and High Availability**: Ensuring data is not lost and is accessible at all times.

Who needs to do it?
Database engineer

Examples: InfluxDB, TimescaleDB, Prometheus.



Driver

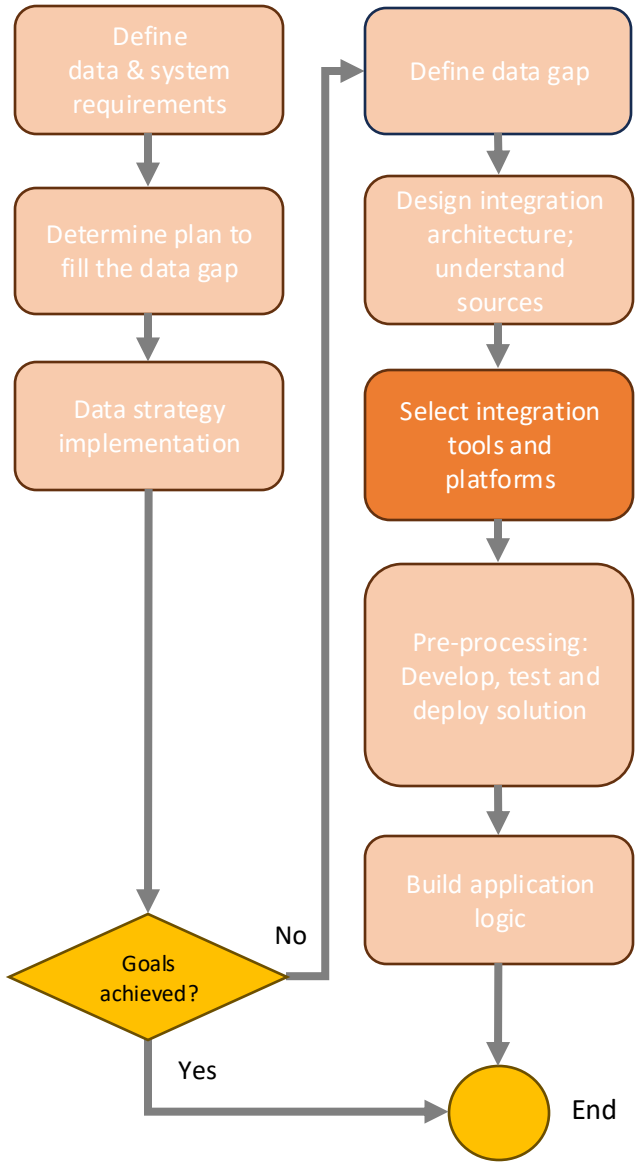
What does this step mean?
A driver in data engineering is a software component that enables a data processing system or application to communicate with a data source, such as a database, data warehouse, or data stream. It serves as an intermediary that translates queries and data operations between the application and the data source, ensuring seamless data access and manipulation.

Why do we need it?
- **Interoperability**: Drivers allow different applications and systems to communicate with various data sources, enabling seamless integration across heterogeneous environments.
- **Abstraction**: They provide a level of abstraction, simplifying the complexities of direct data source interactions for developers and users.
- **Efficiency**: By optimizing data access and query execution, drivers enhance the overall performance of data processing applications.
- **Standardization**: Drivers, especially standardized ones like ODBC and JDBC, ensure a consistent method for accessing different types of databases, reducing the learning curve and development effort.
- **Scalability**: They enable scalable data operations, crucial for handling the increasing volume, variety, and velocity of big data.

What are conditions and requirements for its execution?
- **Compatibility**: The driver must be compatible with both the data source and the application or system using it. This includes matching versions and supported features.
- **Network Accessibility**: The data source must be network-accessible from the system where the driver is being executed, with appropriate network configurations and permissions.
- **Resource Availability**: Sufficient system resources (CPU, memory, network bandwidth) must be available to handle the data operations facilitated by the driver.

Who needs to do it?
Data engineer

Examples: MySQL ODBC Driver, PostgreSQL JDBC Driver, Apache Kafka Connectors



Metadata database

Integrate

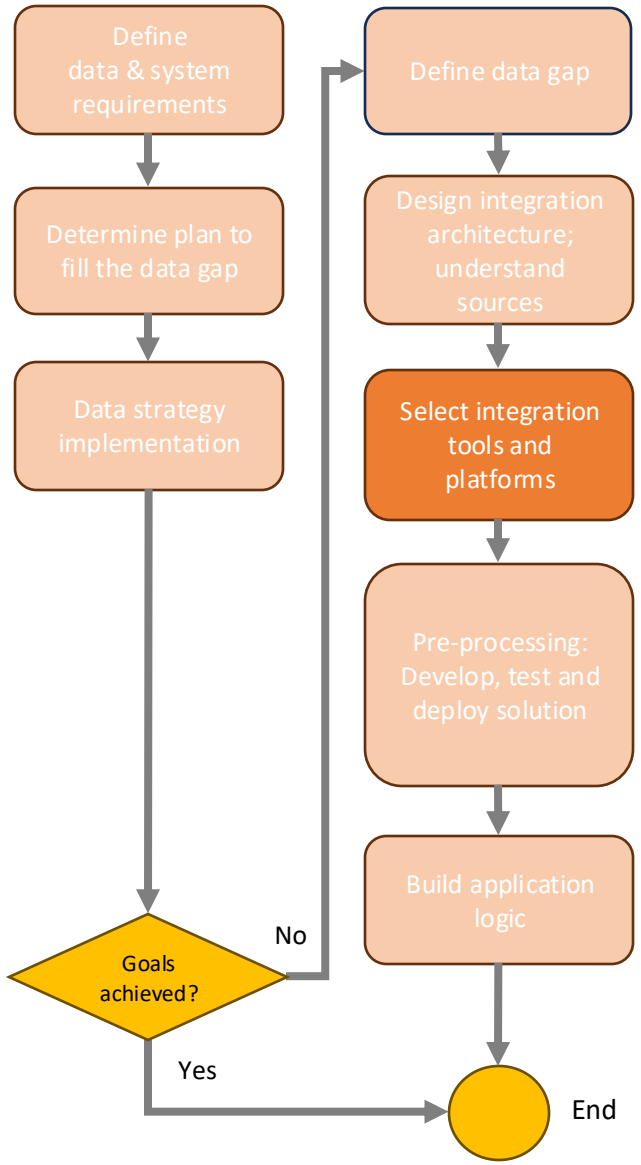
What does this step mean?
A metadata database stores information about other data in the system, such as data source details, schema information, building drawings, and configuration settings.

Why do we need it?
While a timeseries database is ideal for storing time-stamped data, they are not suited for storing unstructured information. A metadata database is optimized for storing relational information.

What are conditions and requirements for its execution?
- **Schema Flexibility**: Ability to handle varying schema structures, especially in environments with diverse data sources.
- **Query Performance**: Efficient querying capabilities for metadata retrieval.
- **Scalability**: Ability to handle growth in metadata size.
- **Consistency and Reliability**: Ensuring the integrity and consistency of metadata.
- **Interoperability**: Compatibility with other system components and databases.
- **Security**: Measures to protect sensitive configuration and schema information.

Who needs to do it?
Database engineer

Examples: PostgreSQL (with JSONB support), MongoDB, Apache Cassandra.



Pre-processing

Integrate

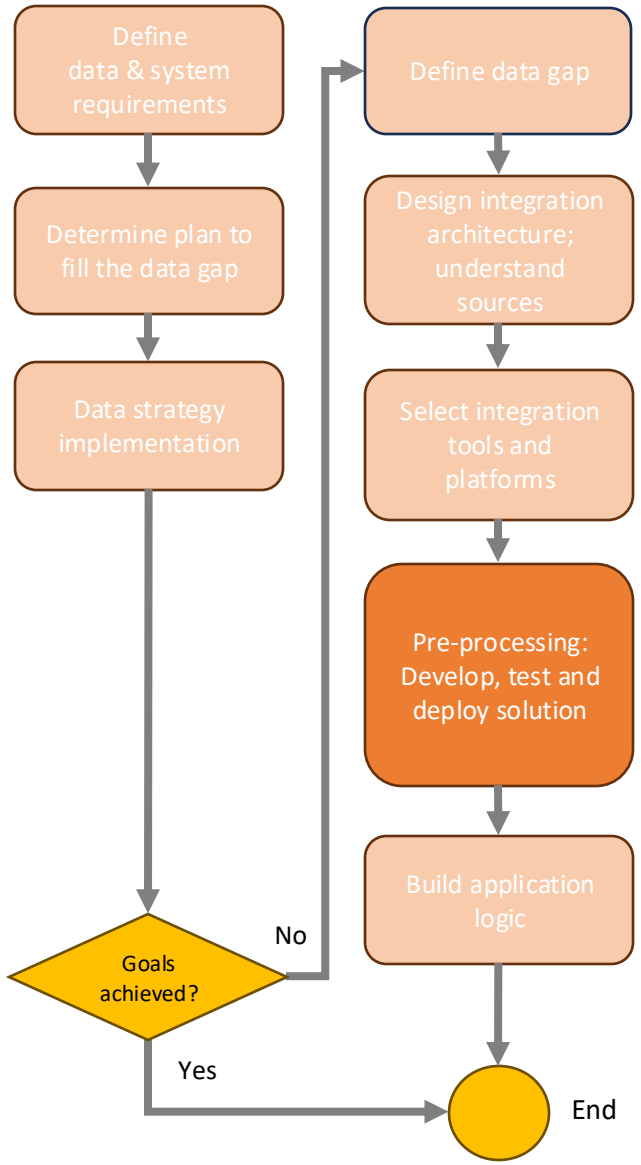
What does this step mean?
Before pushing the data to the message broker and database, the data needs to be clean. This involves **data labelling**, **aggregation**, **filtering**, dealing with **missing data** and fixing **outliers**. After that, the data can be pushed to the message broker. Validation of the data is necessary before final deployment.

Why do we need it?
Oftentimes, data is not extracted in the required form. The labels are not intuitive, there is missing data, or the measurements are wrong (outliers).

Who needs to do it?
Data engineer with a building- and/or facility manager.

Examples are presented in the next slides.

To dive deeper into the preprocessing, see course by Martin WP5



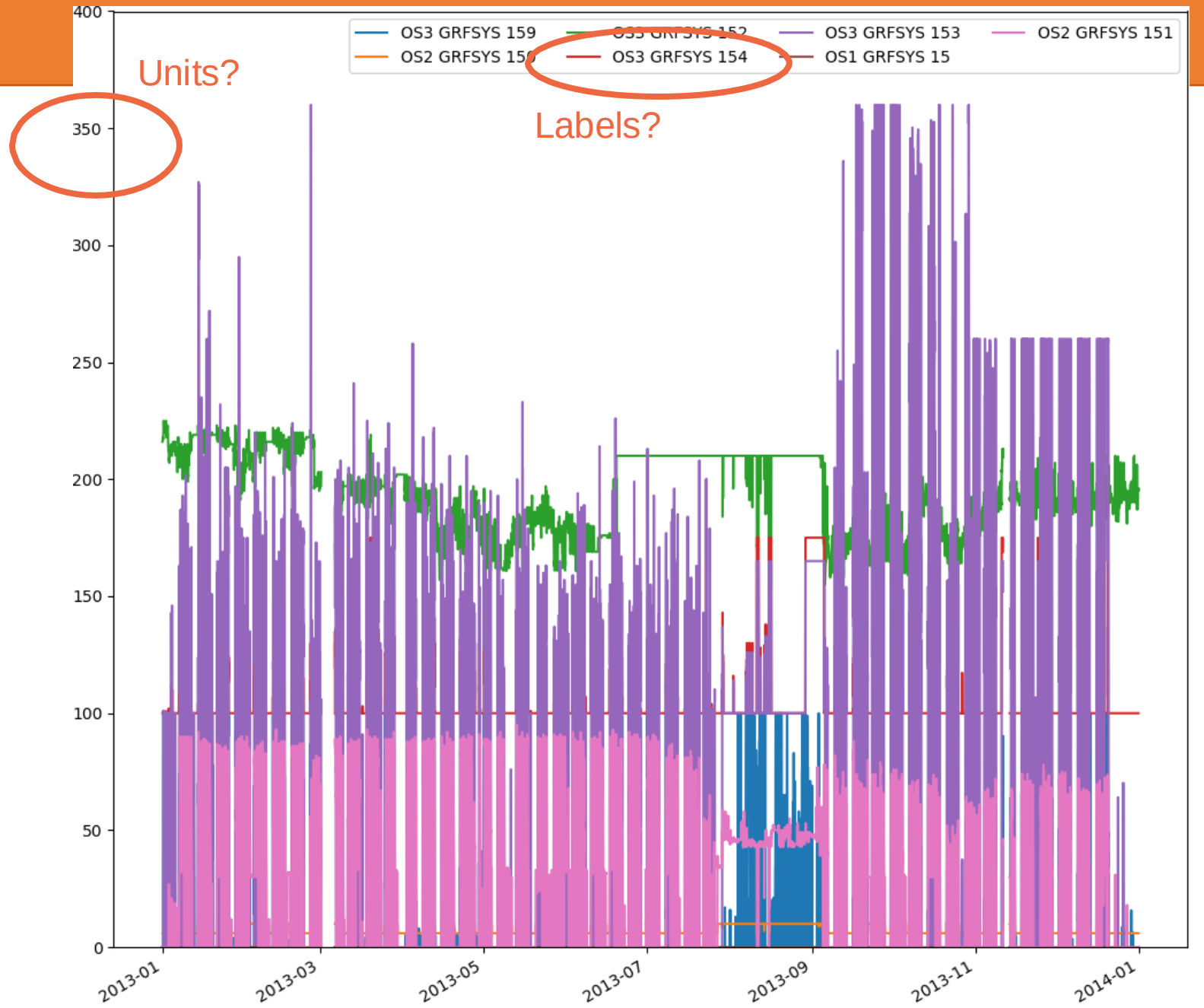
Data labelling

One of the most common problems in smart building applications is inconsistent data labeling.

Smart building applications need knowledge across multiple systems, e.g.: HVAC, fire, lighting, etc. These systems are usually installed by different vendors and follow different naming conventions.

Different buildings and systems use diverging standards and conventions, leading to lots of manual work to adapt procedures from building to building.

Unstructured naming conventions and tagging systems to represent data syntax and semantics make it difficult to understand and interpret the data.



Data labelling

Example of naming convention in Johnson Controls

TU Delft sensor naming convention
(##) ###.XX-##XX-

- (##) – Building number
- ### – System number
- XX – Control engineering code
- XX- – Reporting, measuring and control code

Name	Description
(28) 201.TA-01A--	Vorstgevaar
(28) 302.VA-01A--	Afzuigventilator storing
(28) 201.VT-01A--	Toevoerventilator storing
(28) 201.CP-01A--	Circulatiepomp verwarmer storing
(28) 201.WW-01A--	Warmtewiel storing
(28) 201.VA-01A--	Afvoerventilator storing
(28) 201.CV-02V--	Regelafsluiter koeler
(28) 201.CV-01V--	Regelafsluiter verwarmer
(28) 201.VT-01B--	Toevoerventilator bedrijf
(28) 302.FT-01M--	Flowmeting LBK2
(28) 302.PT-01M--	Afzuigdrukopnemer
(28) 201.TT-02M--	Retourtemperatuur
(28) 201.PT-01M--	Inblaasdrukopnemer
(28) 201.TT-01M--	Inblaastemperatuur
(28) 201.PT-01M--	Afzuigdrukopnemer
(28) 201.MT-01M--	Inblaasvocht
(28) 302.VA-01B--	Afzuigventilator bedrijf
(28) 201.CD-02SW-	Afblaasluchtklep west vrijg.
(28) 201.CD-02SO-	Afblaasluchtklep oost vrijg.
(28) 302.VA-01S--	Afzuigventilato vrijgave
(28) 201.VT-01S--	Toevoerventilator vrijgave
(28) 201.CP-01S--	Circulatiepomp verwarmer vrijg.
(28) 201.WW-01S--	Warmtewiel vrijgave
(28) 201.VA-01S--	Afvoerventilator vrijgave
(28) 201.CP-01B--	Circulatiepomp verwarmer bedrijf
(28) 201.WW-01B--	Warmtewiel bedrijf
(28) 201.VA-01B--	Afvoerventilator bedrijf
(28) 201.WW-01V--	Warmtewiel sturing
(28) 302.VA-01V--	Afzuigventilator sturing
(28) 201.VT-01V--	Toevoervent. sturing
(28) 201.VA-01V--	Afvoervent. sturing
(28) 201.SC-03M--	Signaal toerenreg. VA
(28) 201.SC-02M--	Signaal toerenreg. VA
(28) 201.SC-01M--	Signaal toerenreg. VT
(28) 201.TT-03M--	Aanzuigtemperatuur
(28) 201.TT-07M--	Retourtemp. verwarmer
(28) 201.TT-05M--	Inblaastemp. na ww
(28) 201.TT-04M--	Afblaastemp. na ww
(28) 201.PDT03M--	Drukverschil 1e filter
(28) 201.PDT04M--	Drukverschil 2e filter
(28) 302.CD-01V--	Luchtklep sturing

Building number:
Building 28

System number:
201 = AHU

Control engineering code:
CV = Control valve

Process number

Reporting, measuring and control code:
M--: measurement

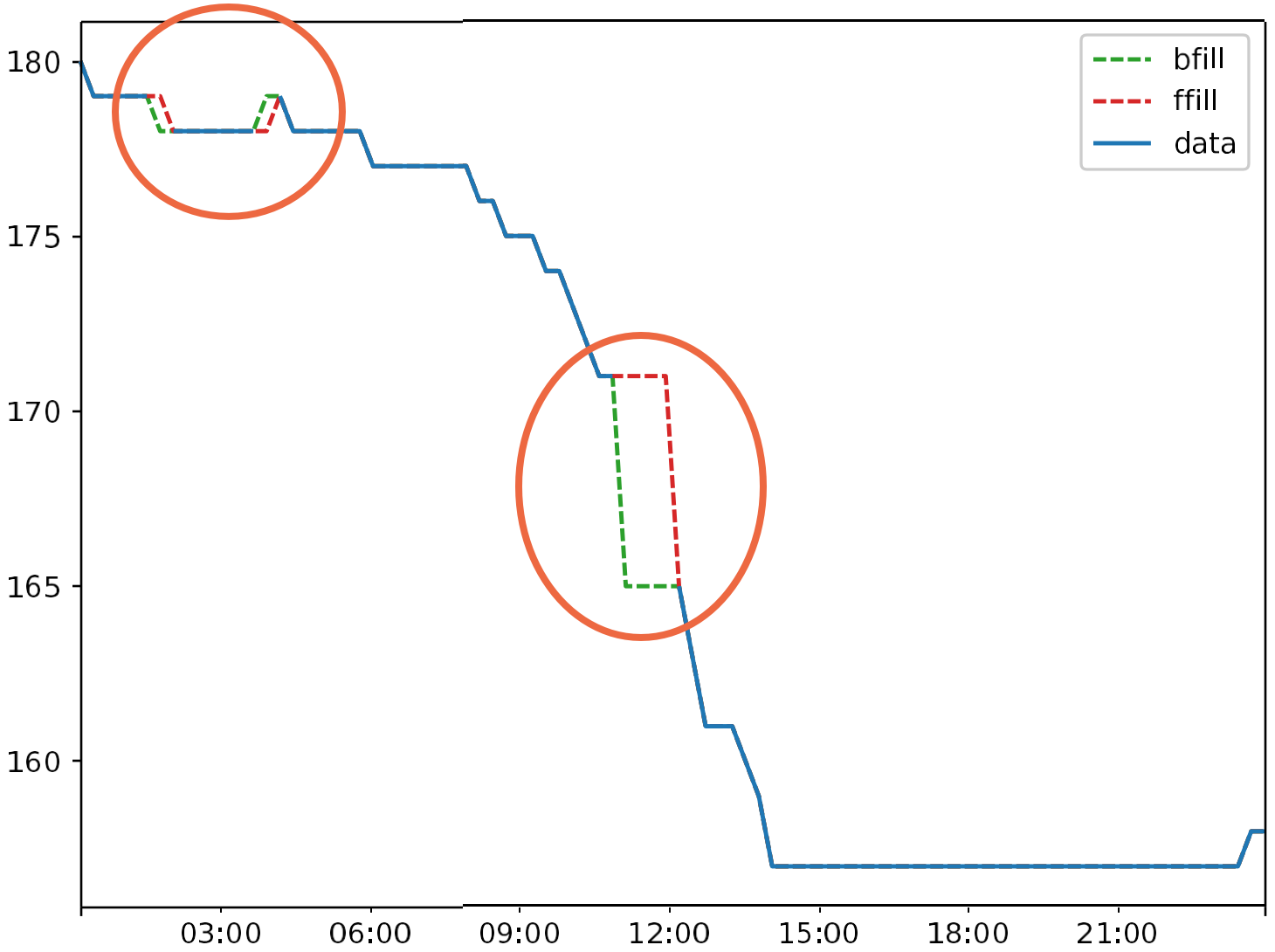
A--	Alarm
B--	Bedrijfsmelding
D--	Dicht
HS--	Hoofdschakelaar
L--	Lokaal bediend
LG--	Lichtgroep
M--	Meting
O--	Open
S--	Schakelen
T--	Telling(er)
V--	Sturing
WS-	Werkschakelaar
W--	Werksetpunt
X--	Instelling (X-as)
XS-	Setpunt verstelling
Y--	Instelling (Y-as)

	sturingen
SU-	urgente storing
SN-	niet urgente storingsmelding
SR-	reset op afstand (GBS)
SB-	brandsturing
SI-	brandschakelaar ventilatie in
SU-	brandschakelaar ventilatie uit
SS-	staffel relais
SRP	resetplus
	meldingen
BR-	reset storing
BI-	herinschakelen ventilatie na brand
BU-	heruitschakelen ventilatie na brand
BV-	voeding aanwezig
L--	regelkast lokaal bediend
BS-	spanningsbewaking stuurstroom (NC)
	alarmen
AB-	brandmelding RK-01 BMC
AN-	netwachter
AS-	sabotage
AI-	installatie automaten

Missing data

Techniques used for treating erroneous and missing values vary from one application to another:

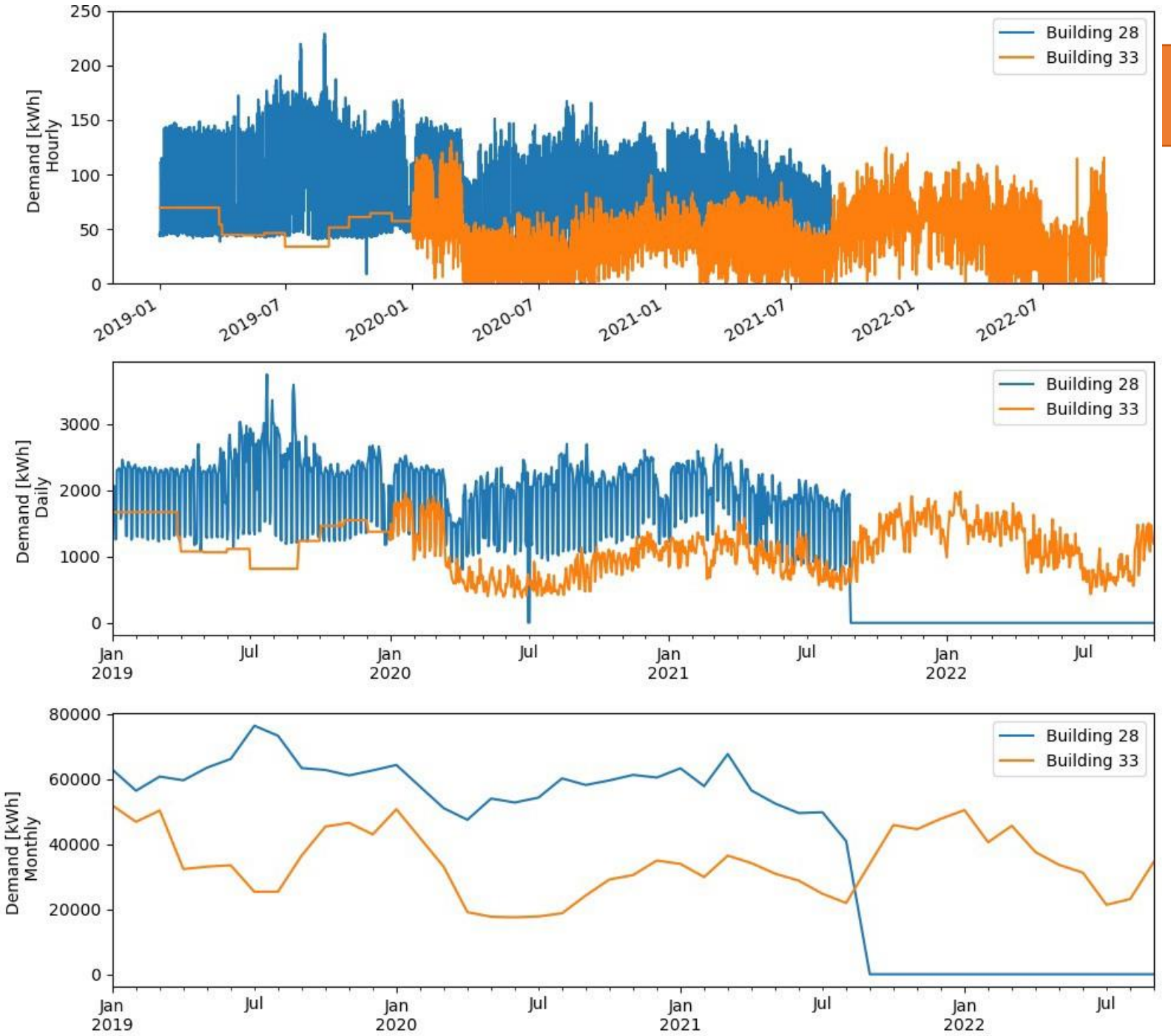
- replacing with next or previous value
- Interpolation
- Rolling average



Downsampling

When gathering frequency does not match the intended application

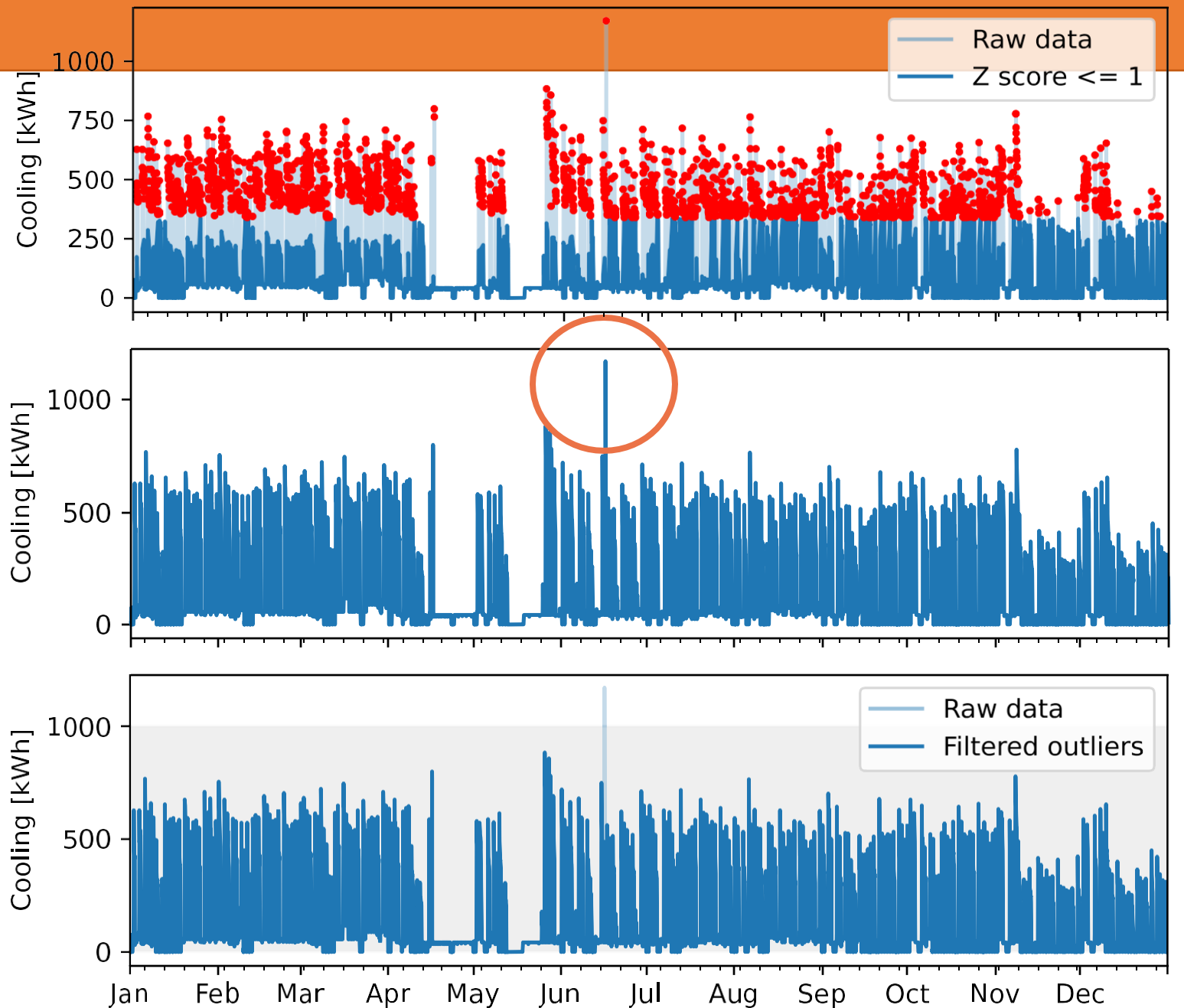
- Choice of frequency: hourly, daily, monthly, etc.
- Choice of down sampling method
  - Mean: e.g., operating temperature, pressure
  - Sum: e.g., energy demand



Outliers

Removing unexpected outliers to ensure they do not influence the intended application:

- expected range of values (if available)
- Z-scores: need to pick a reasonable value

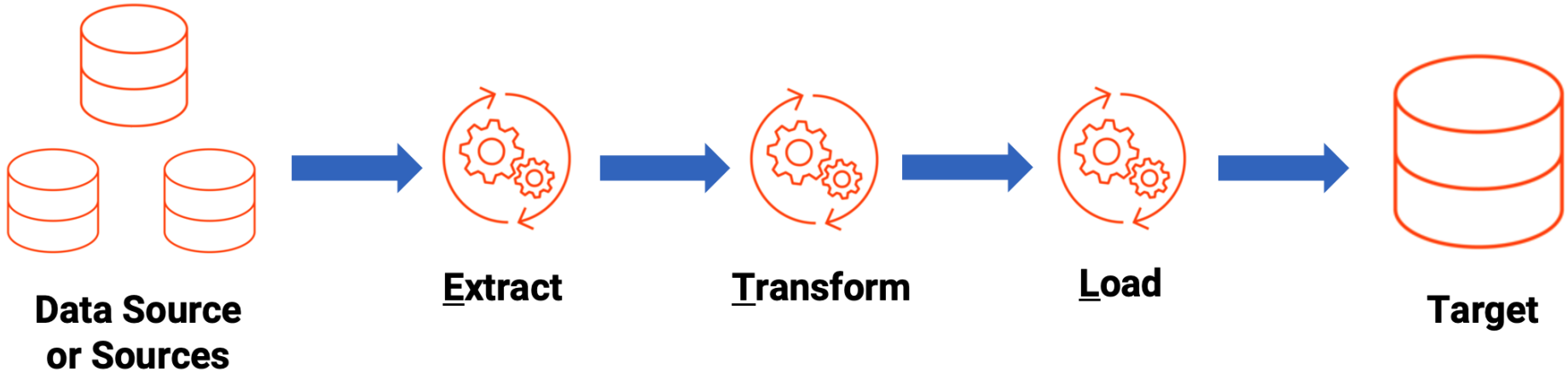


Integration

What does this step mean?
When the data preprocessing is finished, it can finally be integrated. The data can be pushed to the message broker, which will in turn store the data in the database. While performing this test, it is wise to first try it out with a small subset of the data and validate that the data comes in as expected.

What are conditions and requirements for its execution?
The tools like the message broker, and database need to be in place. Furthermore, the previously mentioned preprocessing needs to be performed on the data to have a proper Extract Transform and Load (ETL) pipeline.

Who needs to do it?
Data engineer

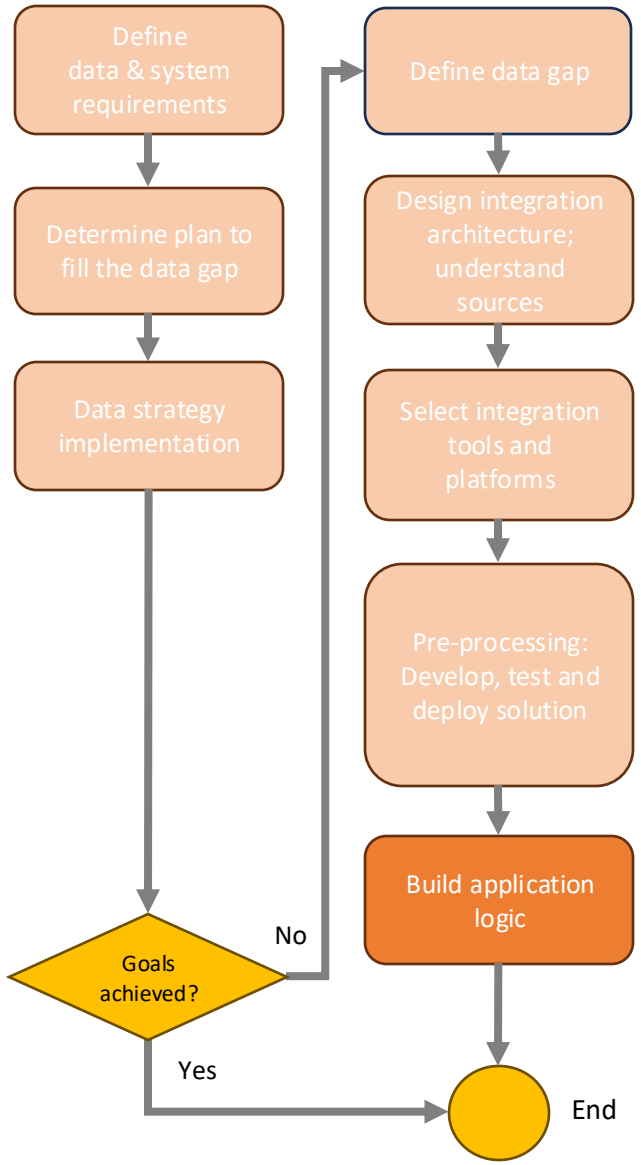


Build application logic

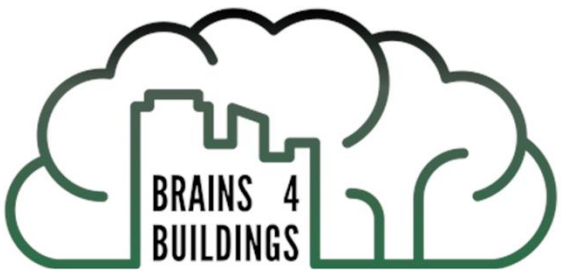
Integrate

What does this step mean?
Finally, you can go ahead with building an intelligent building with AI, MPC, 4S3F fault detection methods, Bayesian networks, whatever can be dreamed up to optimize the assets performance.

Who needs to do it?
Data scientists



This Roadmap is a part of the Brains for Buildings (B4B) project. This is a multi-year, multi-stakeholder project that aims to develop smart building methods to enhance operations in buildings by reducing energy consumption, increasing energy flexibility, increasing occupant comfort, and improving installation maintenance costs. This will be achieved by developing faster and more efficient Machine Learning and Artificial Intelligence models and algorithms. The project is geared towards existing utility buildings, such as commercial and institutional buildings.



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