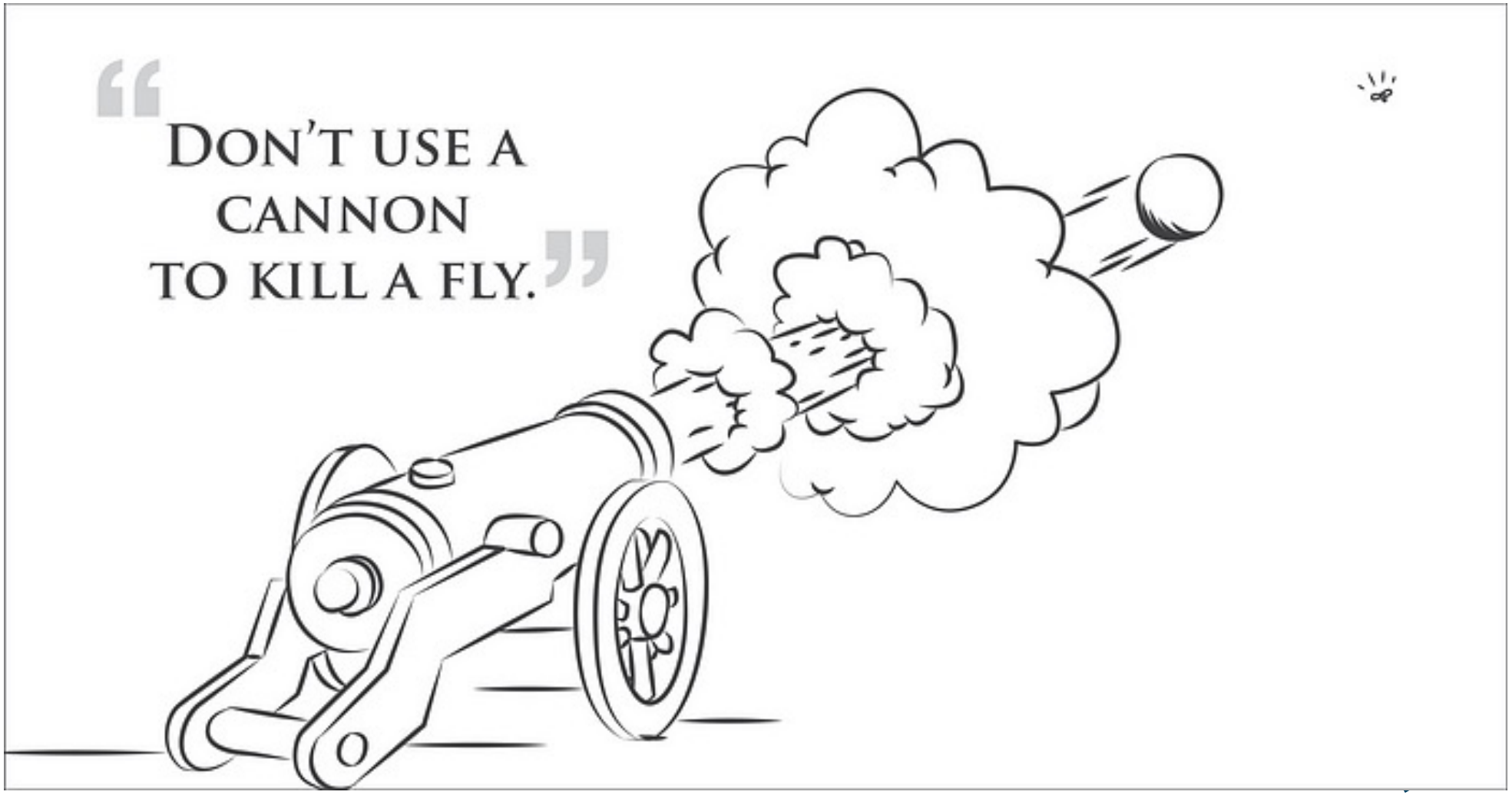
Beware of the black box

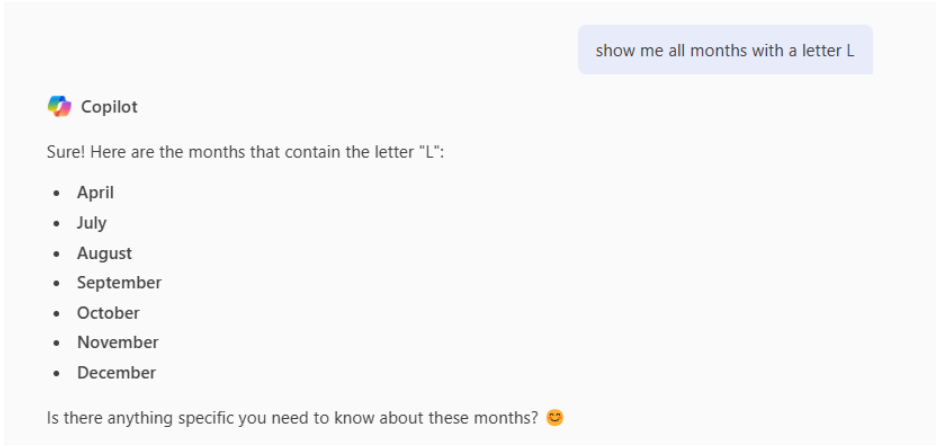
PV Performance Modeling Collaborative Workshop

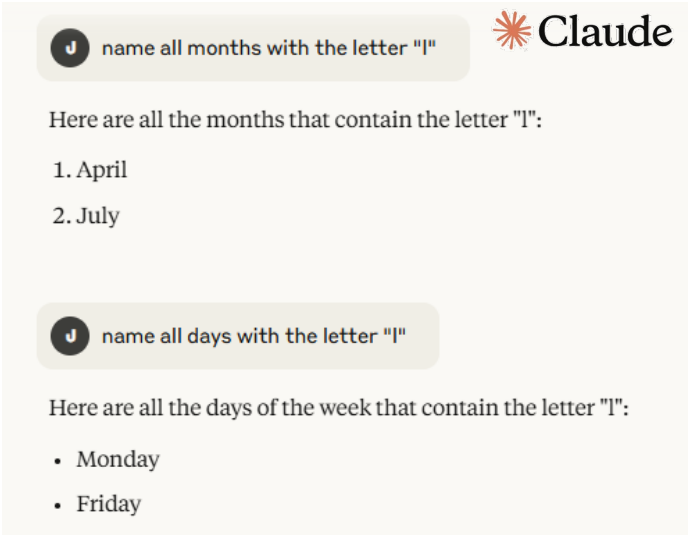
Albuquerque, NM

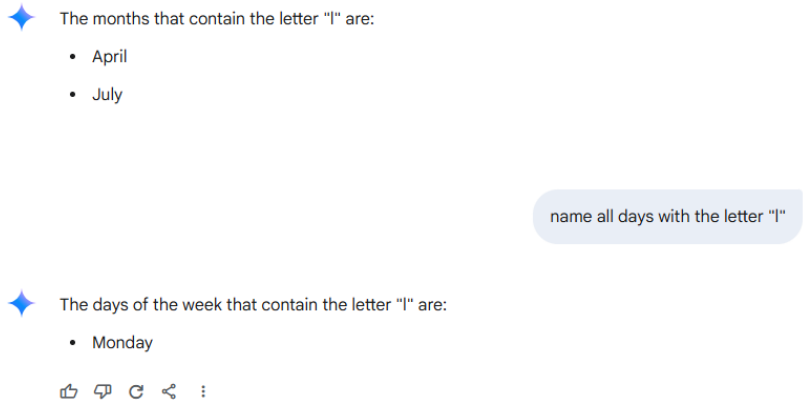
Julien Deckx

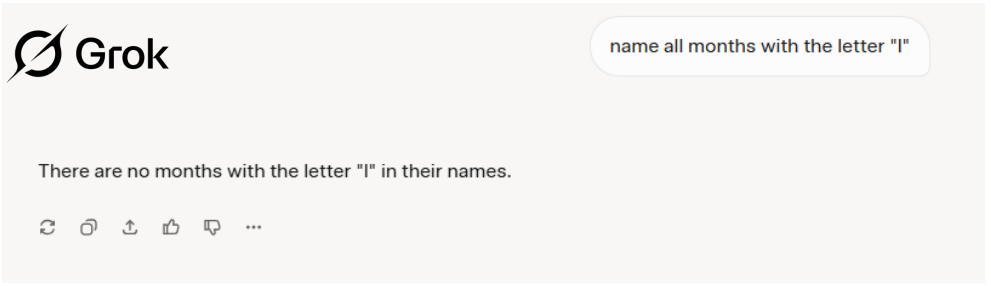
2025-05-14


“DON’T USE A CANNON TO KILL A FLY.”







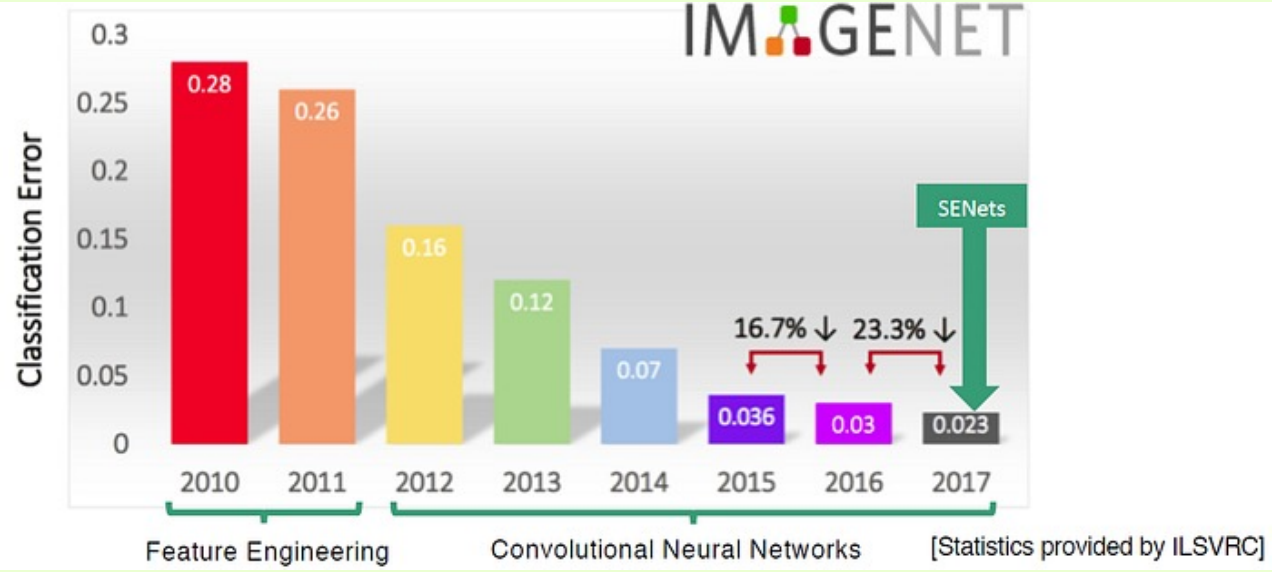


Rule-based if you can, machine learning if you must

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The revolution in image analysis

Deep learning fueled the jump in image recognition performance



Source: https://medium.com/@prudhvi.gnv/imagenet-challenge-advancement-in-deep-learning-and-computer-vision-124fd33cb948

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The sweet spot for deep learning

When does deep learning make sense?

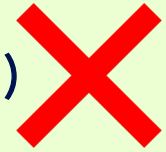
- **Hard or impossible to define a set of features**
  - Image recognition
  - Language recognition
  - Robotics
- **Availability of a large amount of labeled data (OR unsupervised)**
  - Labeled pictures on the internet
  - Transcribed text
  - (Virtual) training of robots

The sweet spot for deep learning

How about solar performance analytics (based on monitoring data)?

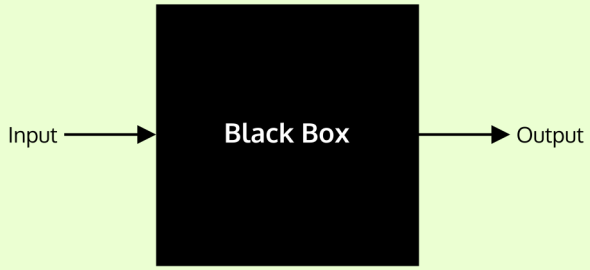
- **Hard or impossible to define a set of features** 

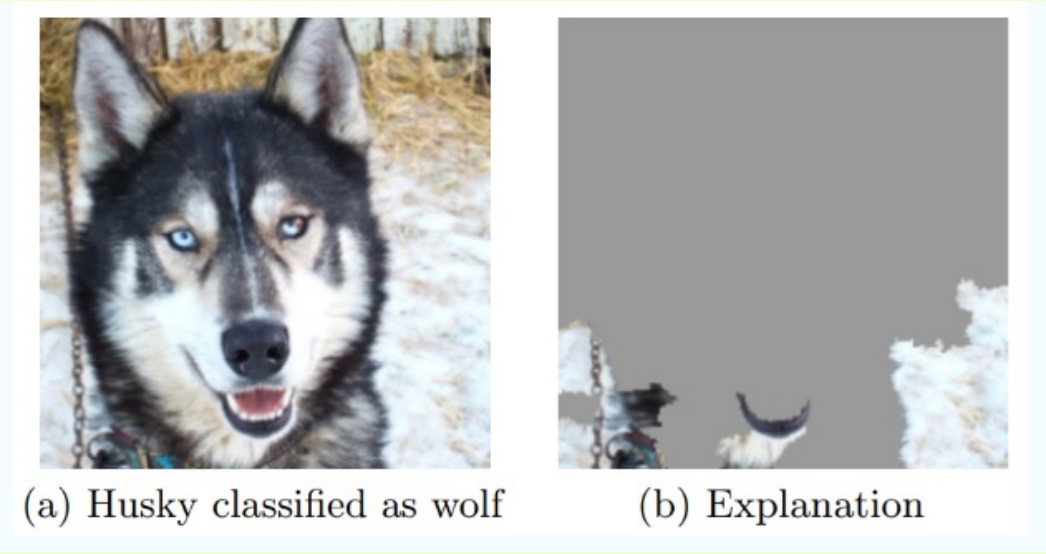
  Plant metadata
  Irradiance
  Temperature
  Wind speed
  Current
  Voltage
  Tracker angles
  Curtailment setpoint

- **Availability of a large amount of labeled data (OR unsupervised)** 

Beware of the black box

The risks of machine learning



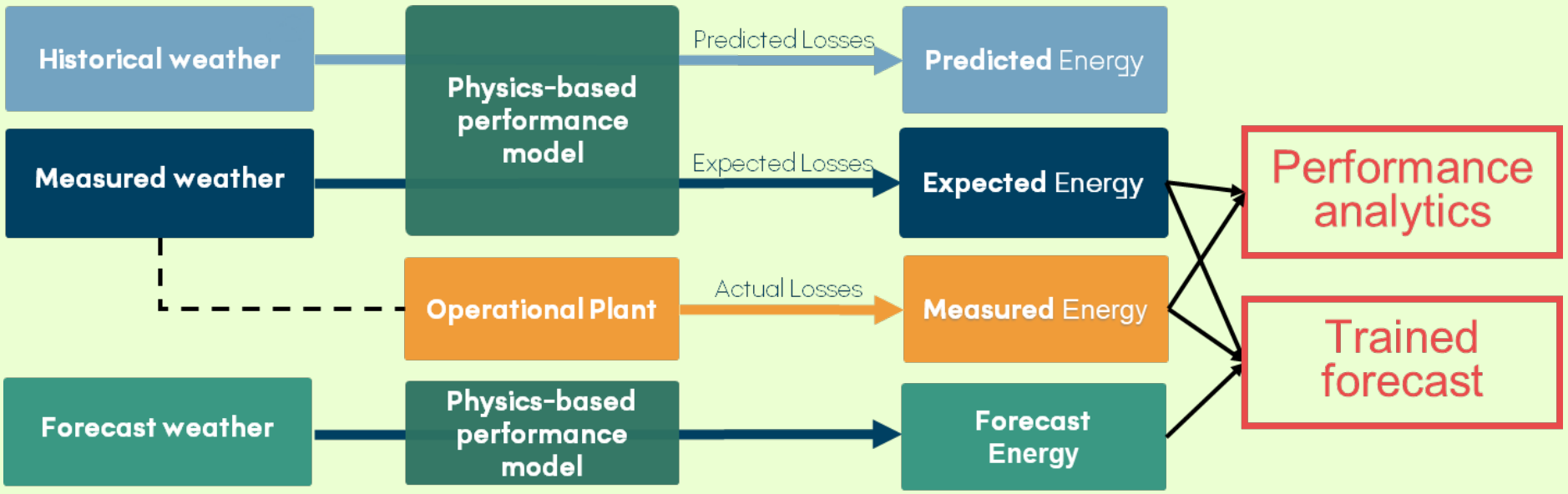

(a) Husky classified as wolf (b) Explanation

Source: https://www.codecademy.com/article/dangers-of-the-black-box

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3E's grey-box approach

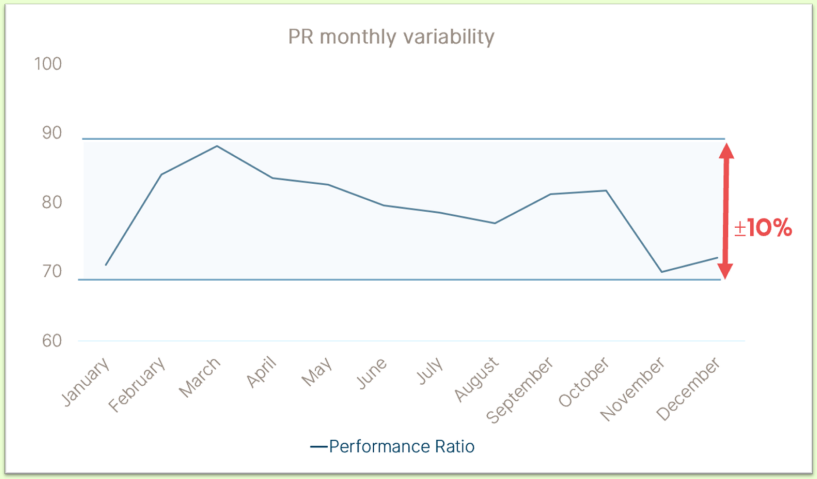
Machine learning combined with a white-box performance model



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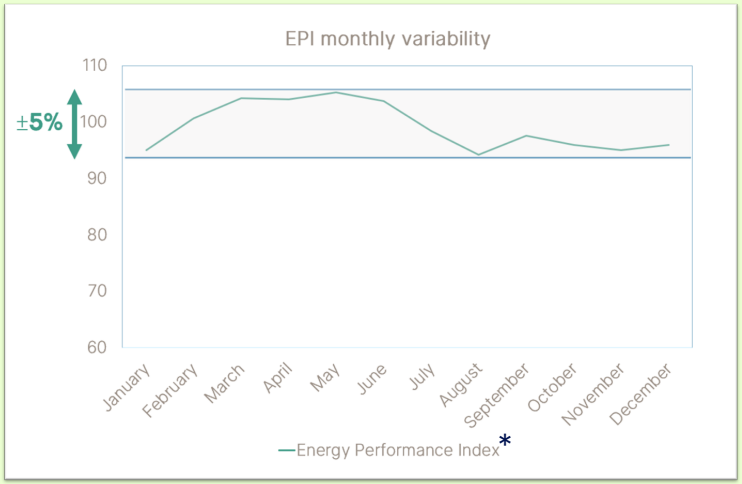
The power of performance modeling

Higher accuracy to detect underperformance



Physics-based ("white box") performance model

Clipping
Temperature losses
Inter-row shading
…

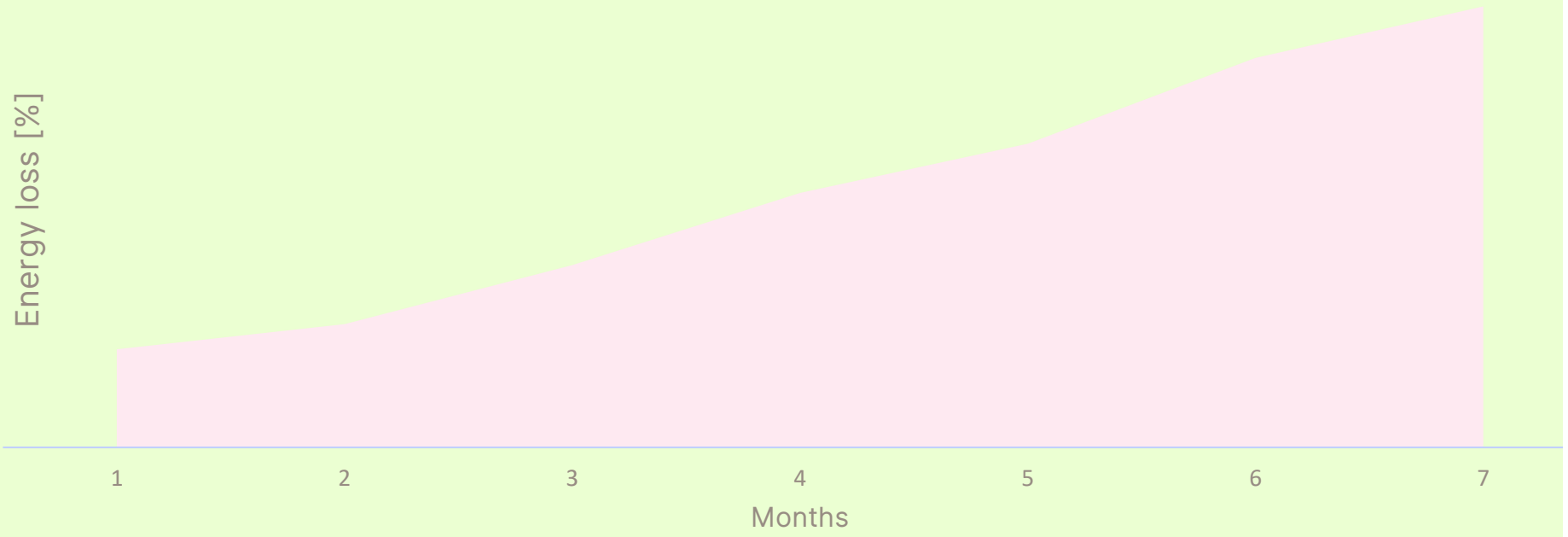


* Energy Performance Index= Measured Energy / Expected Energy (IEC TS 61724-3)

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Beware of the black box – pt 2

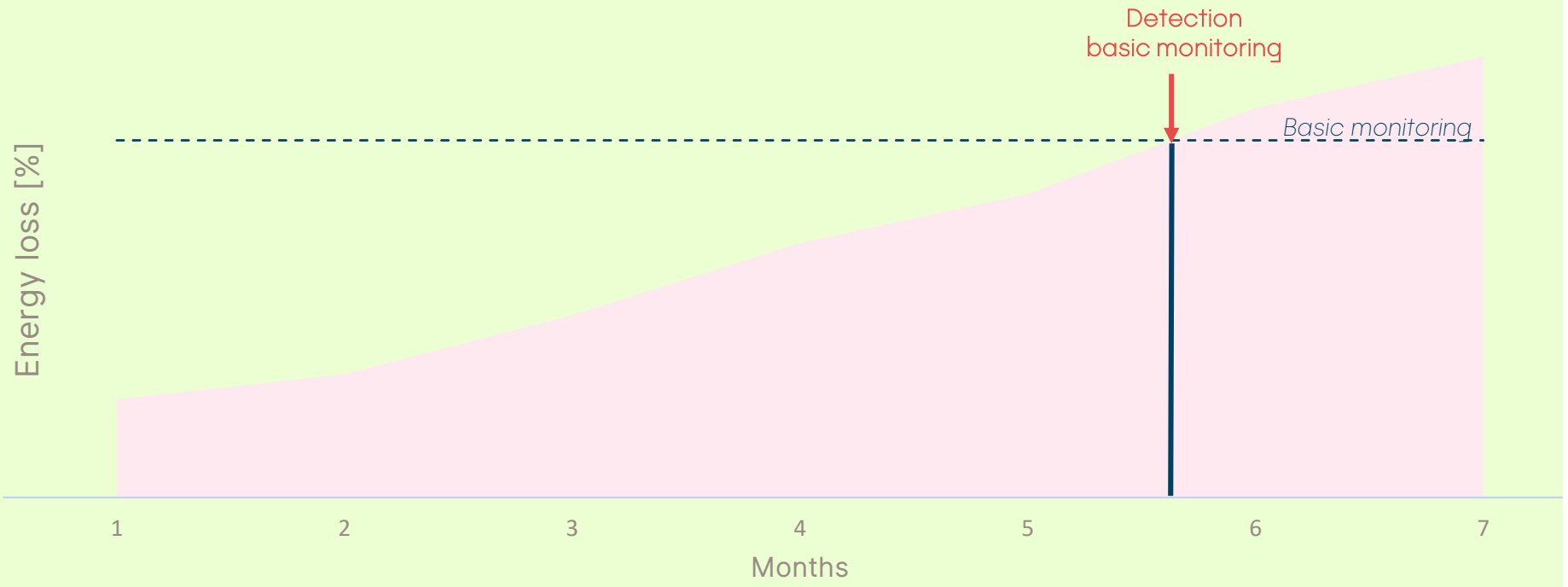
Using a performance model (PM) for underperformance detection



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Beware of the black box – pt 2

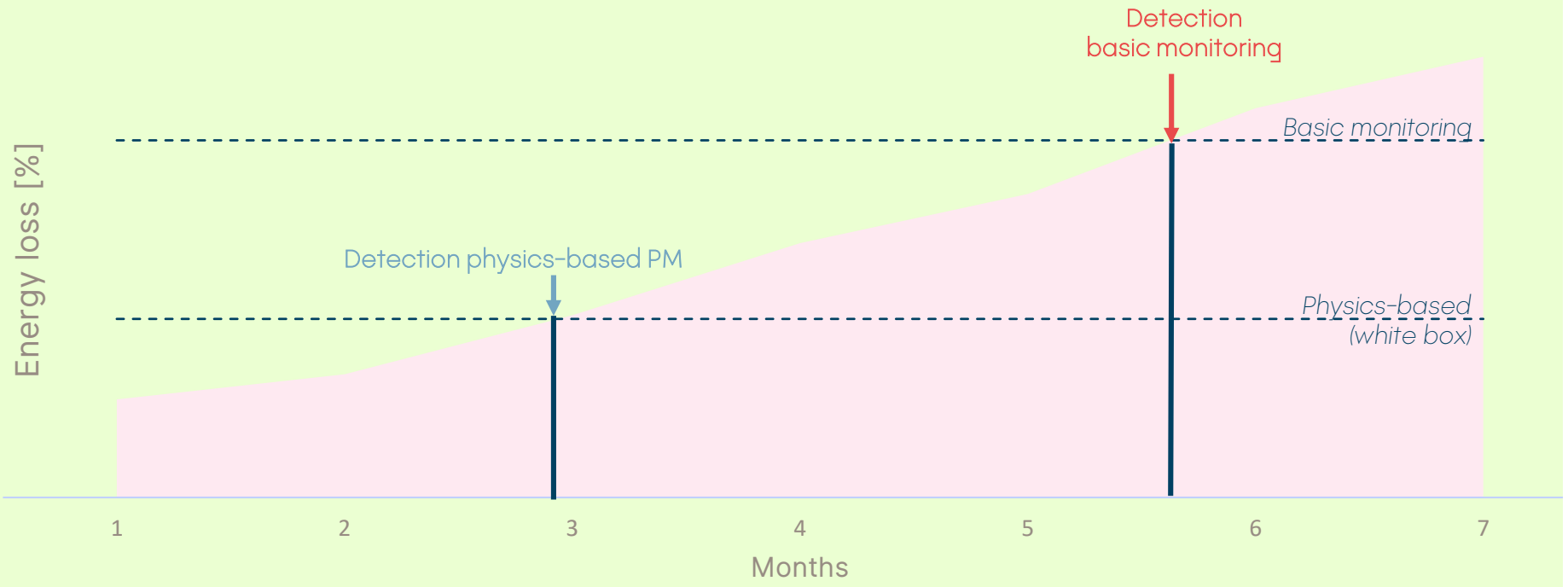
Using a performance model (PM) for underperformance detection



3E document confidentiality classification: general public

Beware of the black box – pt 2

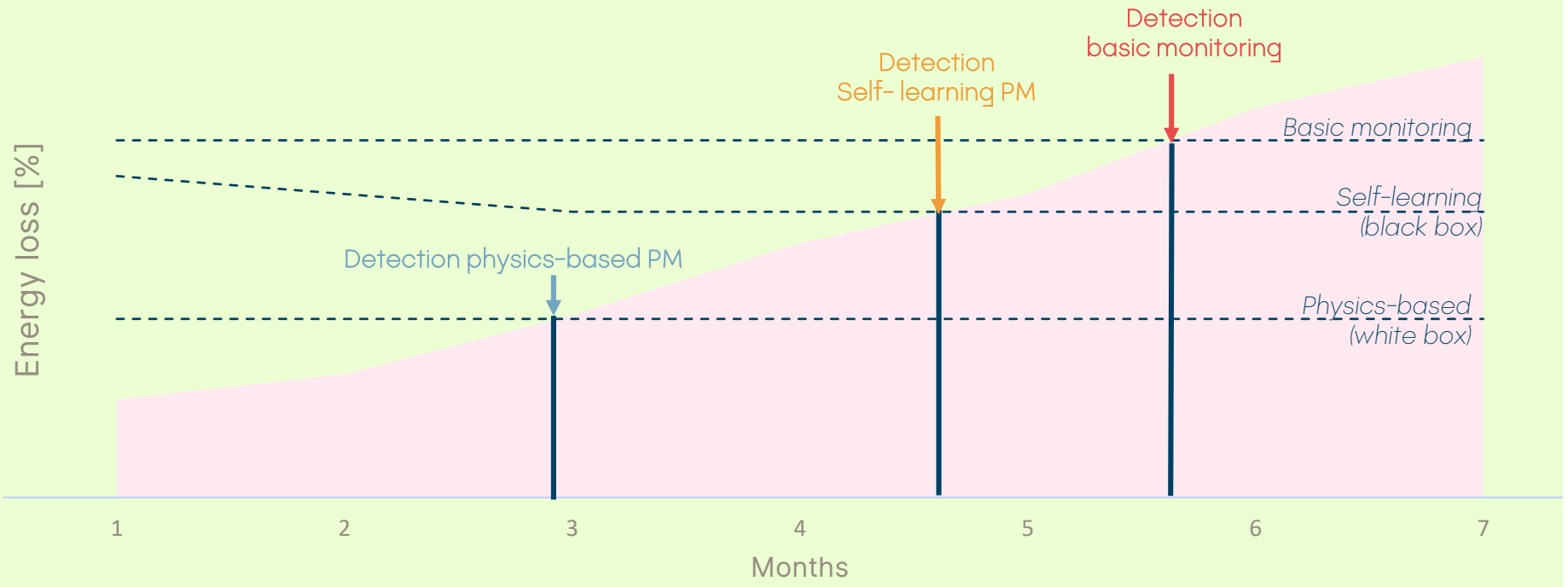
Using a performance model (PM) for underperformance detection



3E document confidentiality classification: general public

Beware of the black box – pt 2

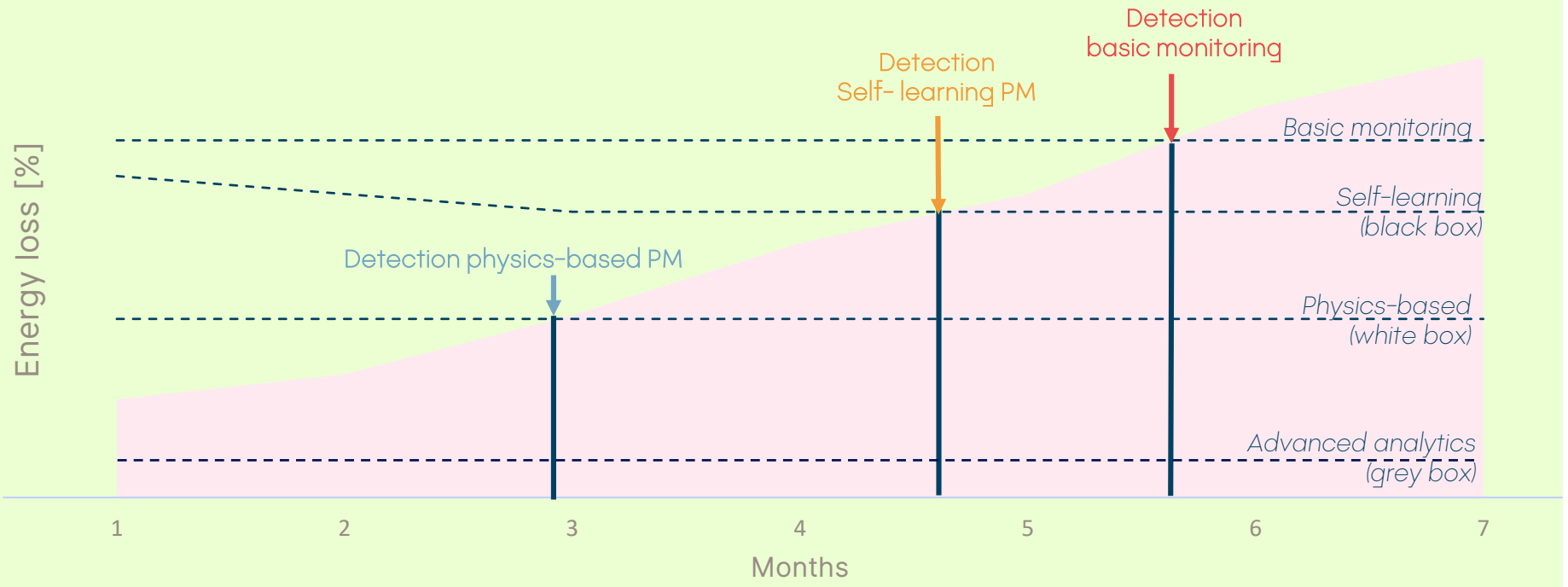
Using a performance model (PM) for underperformance detection



3E document confidentiality classification: general public

Beware of the black box – pt 2

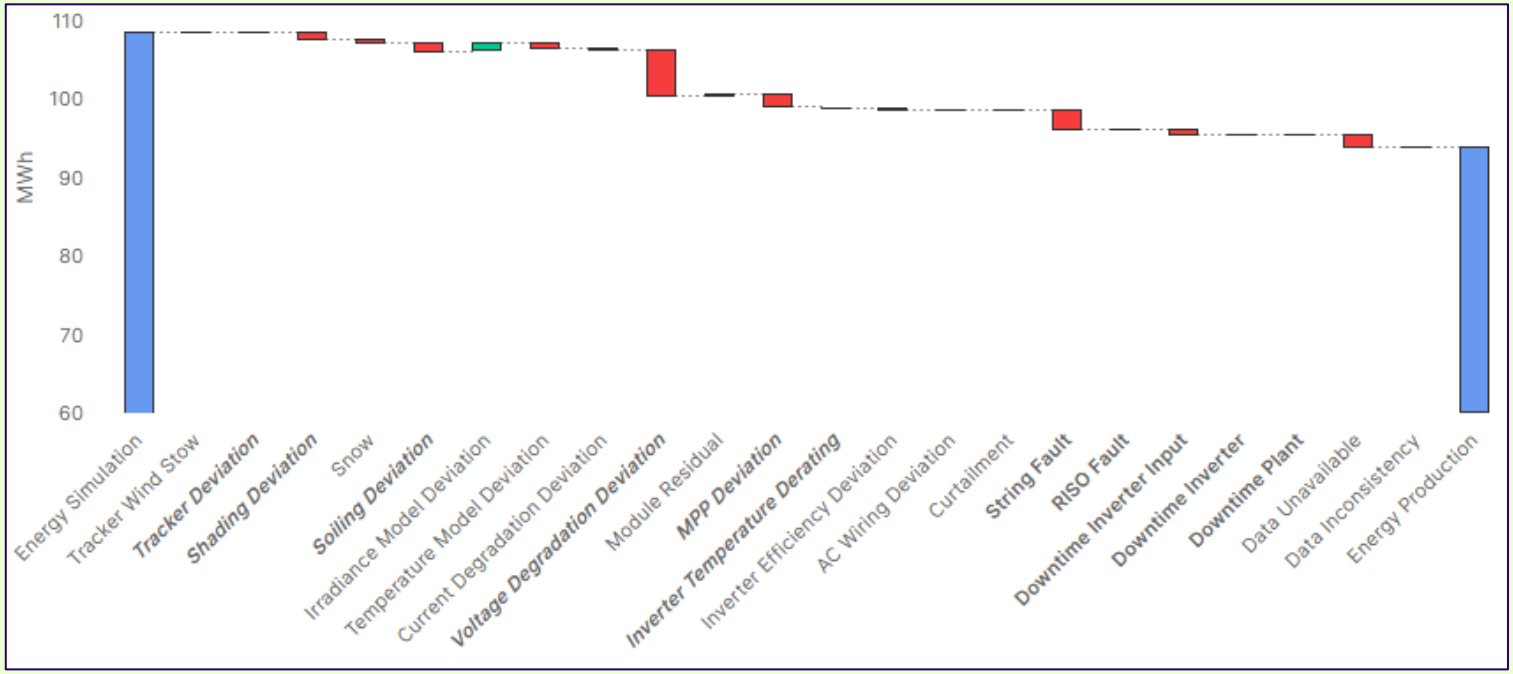
Using a performance model (PM) for underperformance detection



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Performance analytics

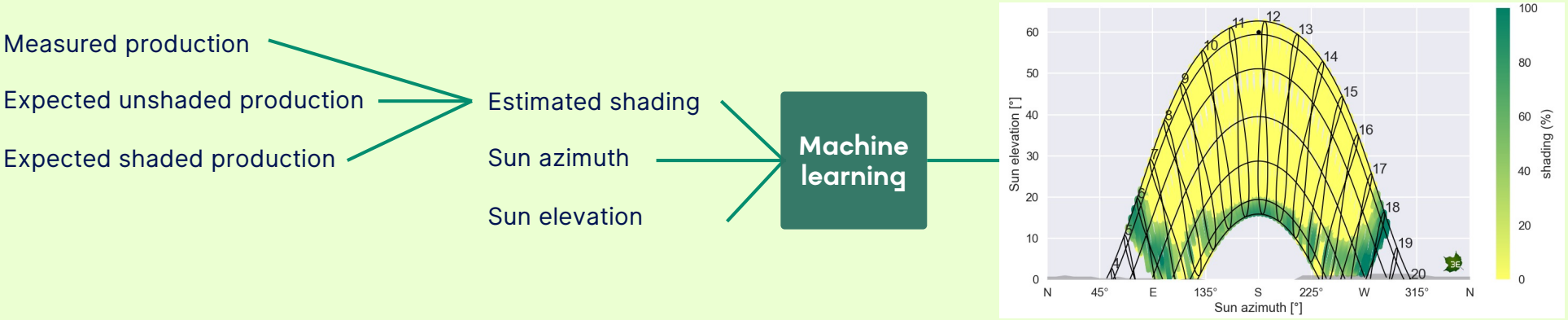
Full analysis of gap between expected and measured energy



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Shading loss quantification

A good example of grey-box approach

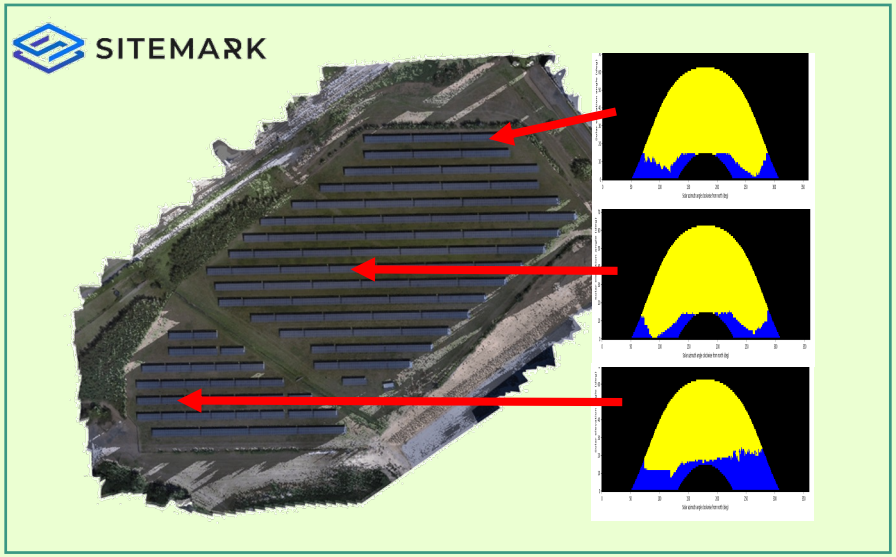


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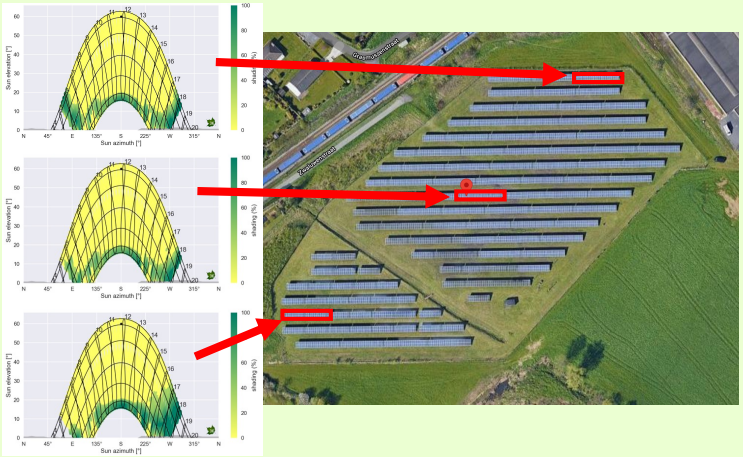
Shading loss validation

Comparison to calculated loss with 3D drone image

Shading predicted with 3D profile identification for points in bottom row



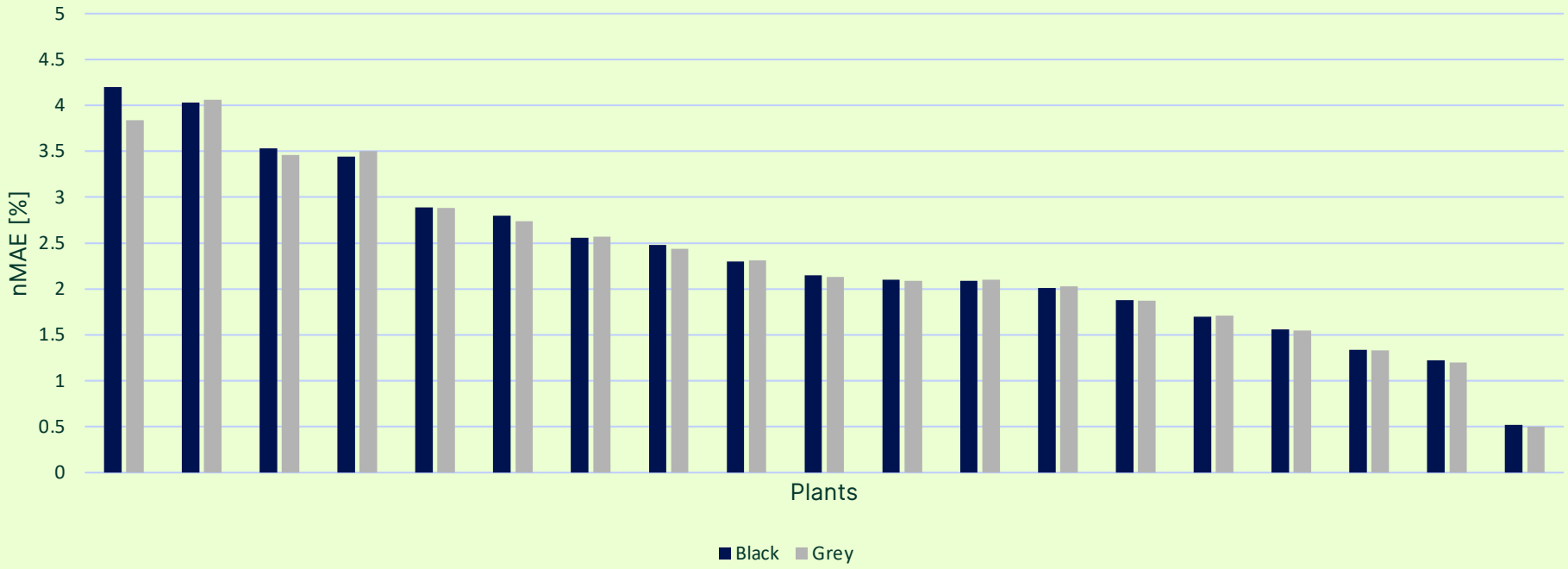
Shading detected by solar analytics from PV array production data



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Production forecast

Comparing pure black box approach to others

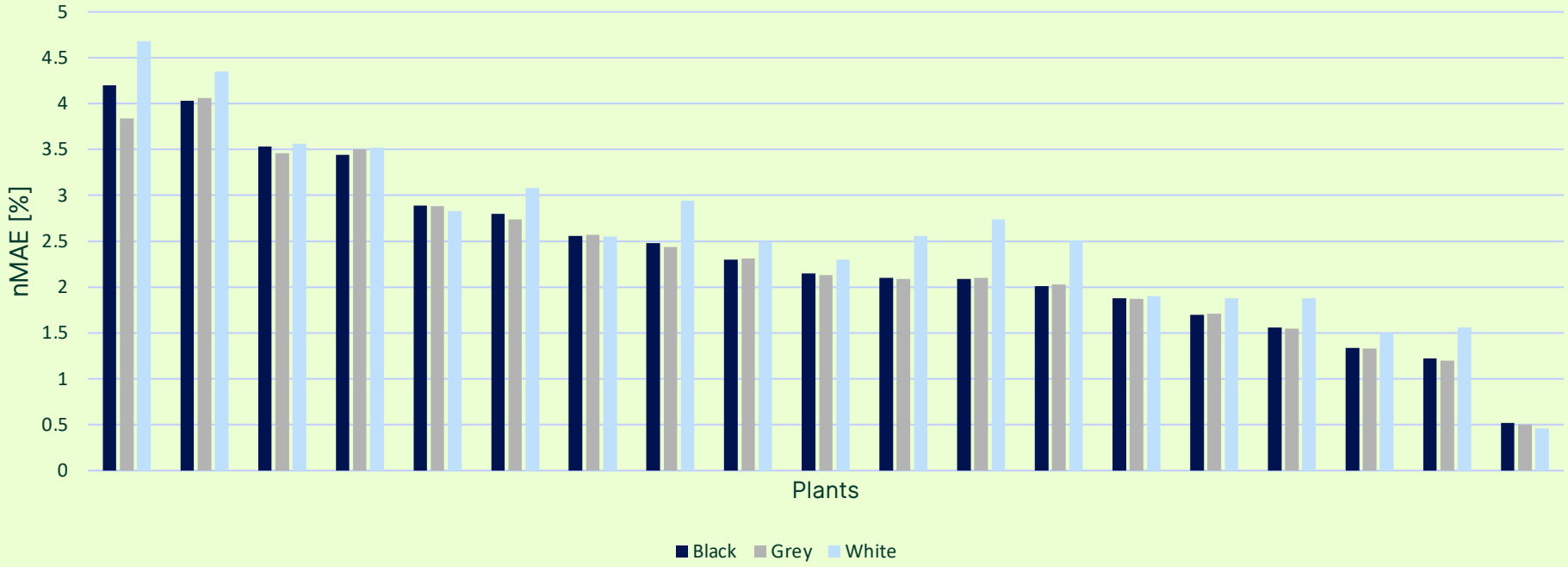


Note: measured weather data was used instead of forecast

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Production forecast

Comparing pure black box approach to others

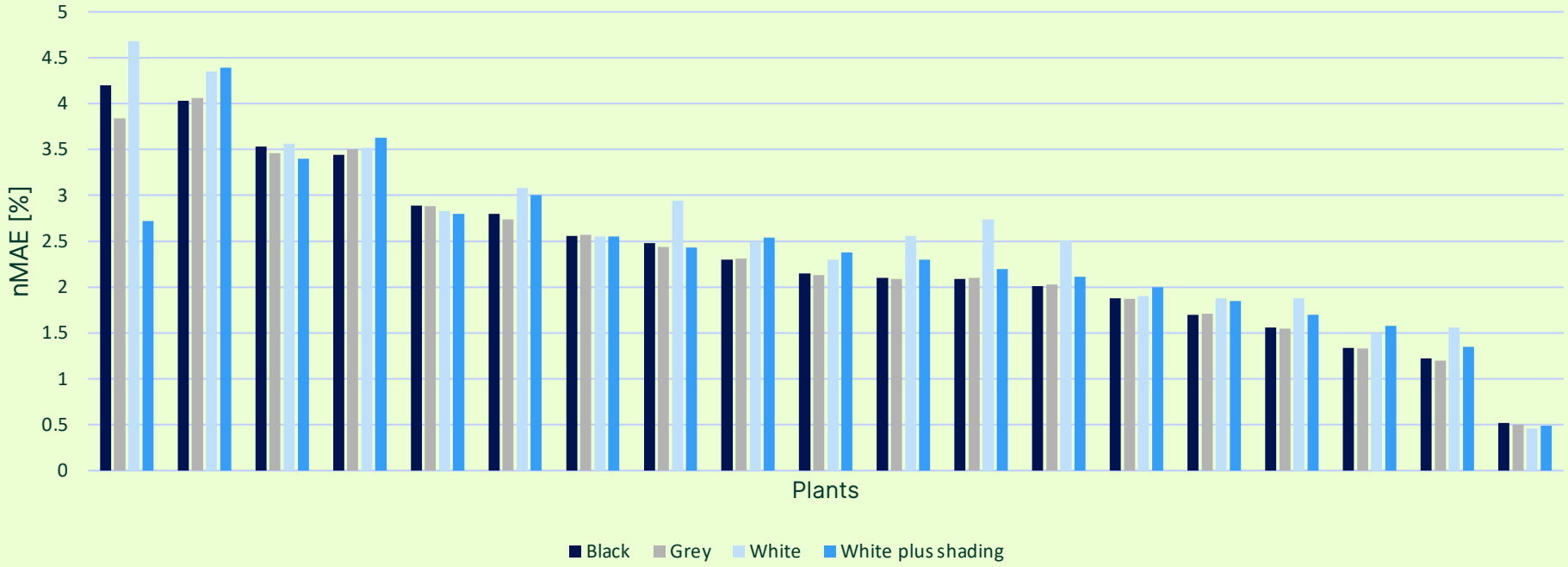


Note: measured weather data was used instead of forecast

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Production forecast

Comparing pure black box approach to others



Note: measured weather data was used instead of forecast

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Conclusions

- Use rule-based algorithms if you can, machine learning if you must
- When you do use machine learning, combine with rule-based algorithms, even if it's just as a baseline/sanity check
- The advantages of grey-box performance analytics
  - Not biased by existing underperformance during training period
  - Faster results as no training period required
  - More transparency and robustness of categorization
  - Bridging the business plan by using the same performance model

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Thank you

Contact person

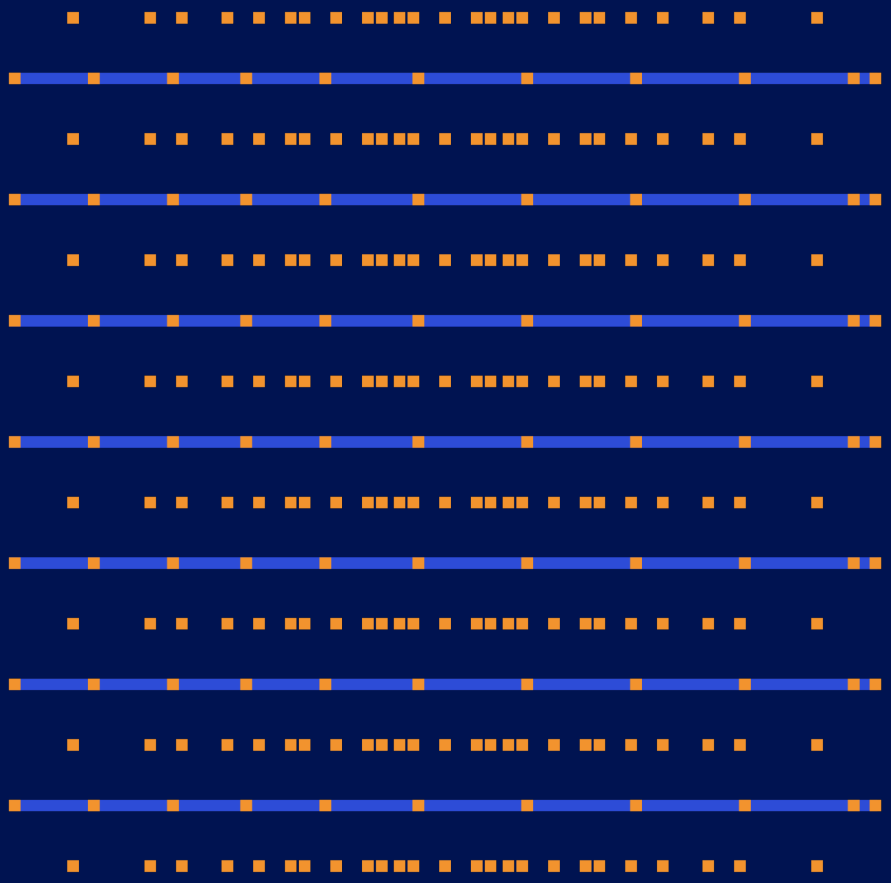
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