Broaden the Operation Window for a Batch Distillation

Jan Schöneberger[1], Burcu Aker[1], Armin Fricke[1],Michael Kawohl[2], Christoph Hiller[2], Valentin Khaydarov[3]

[1]Capital-Gain Consultants, [2]Evonik, [3]AI-incubator lab at TU Dresden
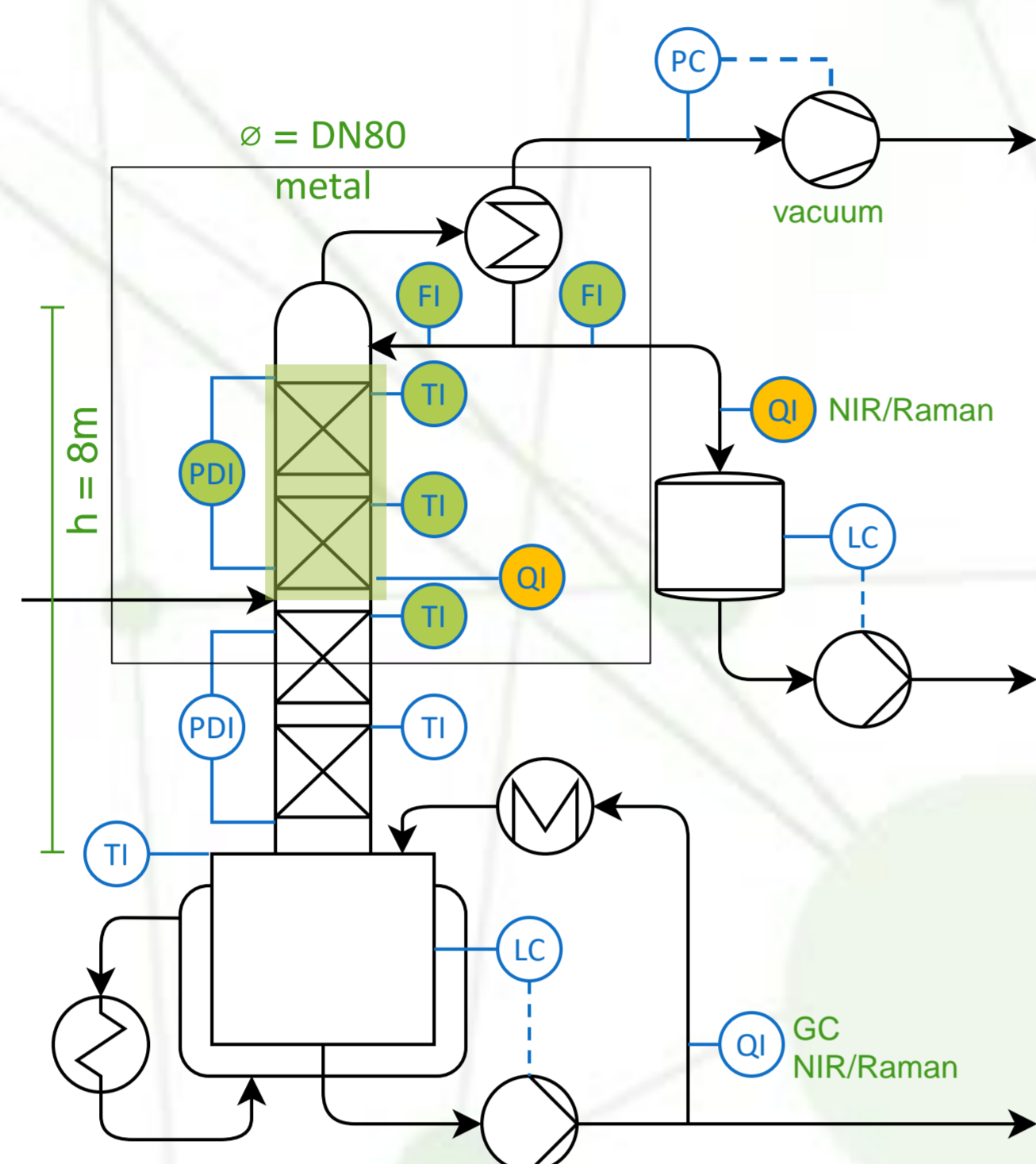
Distillation column

Setup

- Well equipped distillation column
- Online analysers

Operation scenarios

- Continuous operation
- Batch operation
- Dedicated failure scenarios (flooding)

Use case description

Flooding – common suboptimal process condition wherein the separation performance is significantly reduced due to excessive vapour flow. It is detected by a sharp increase in **column differential pressure.**

How can we put the measured variables (mainly pressure drop) into correlation with the product quality?

Goal: **hybrid description of multidimensional non-orthogonal operation window of batch distillation column**

Data: substance composition at inlet and outlet, pressure difference, liquid and vapour flow rates, temperatures, reboiler duty

Load dependent separation efficiency

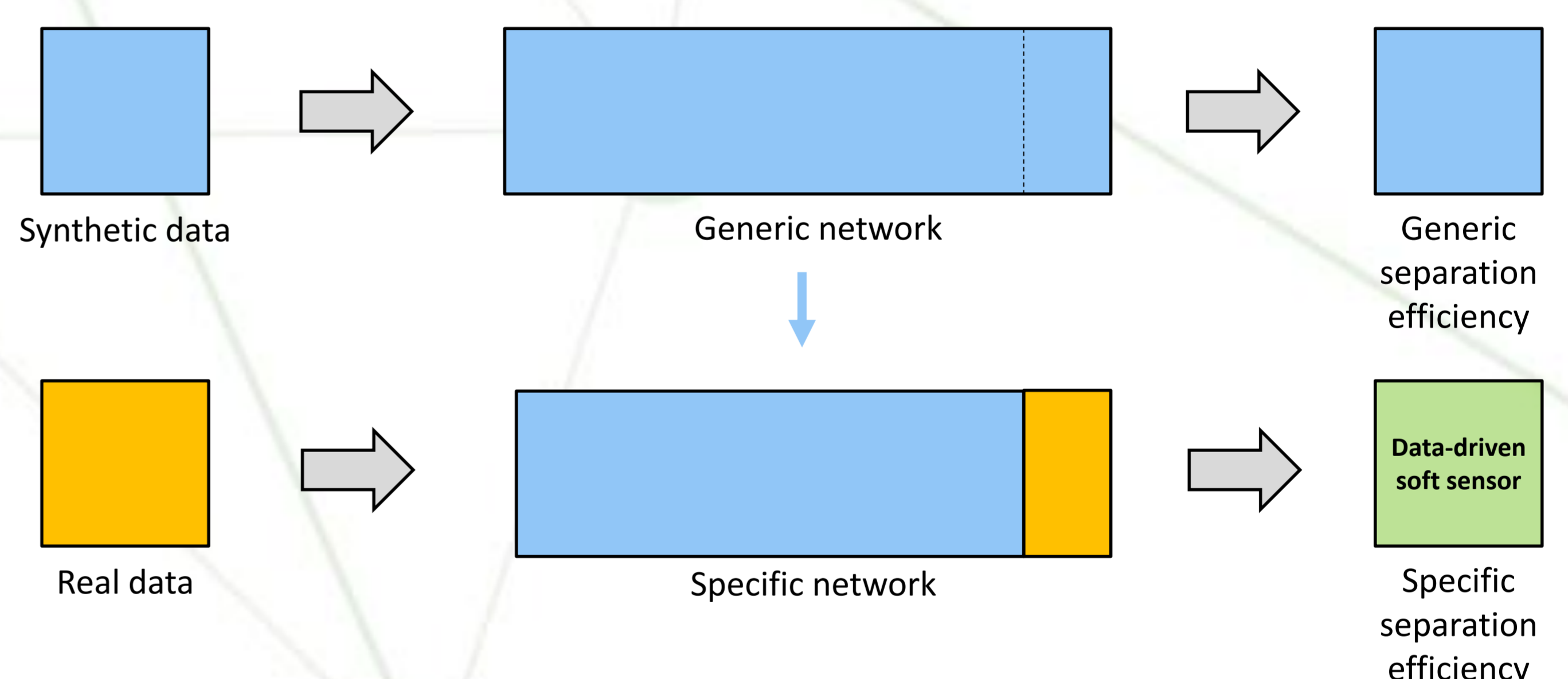F-factor (gas load factor) as an important measure

[1]
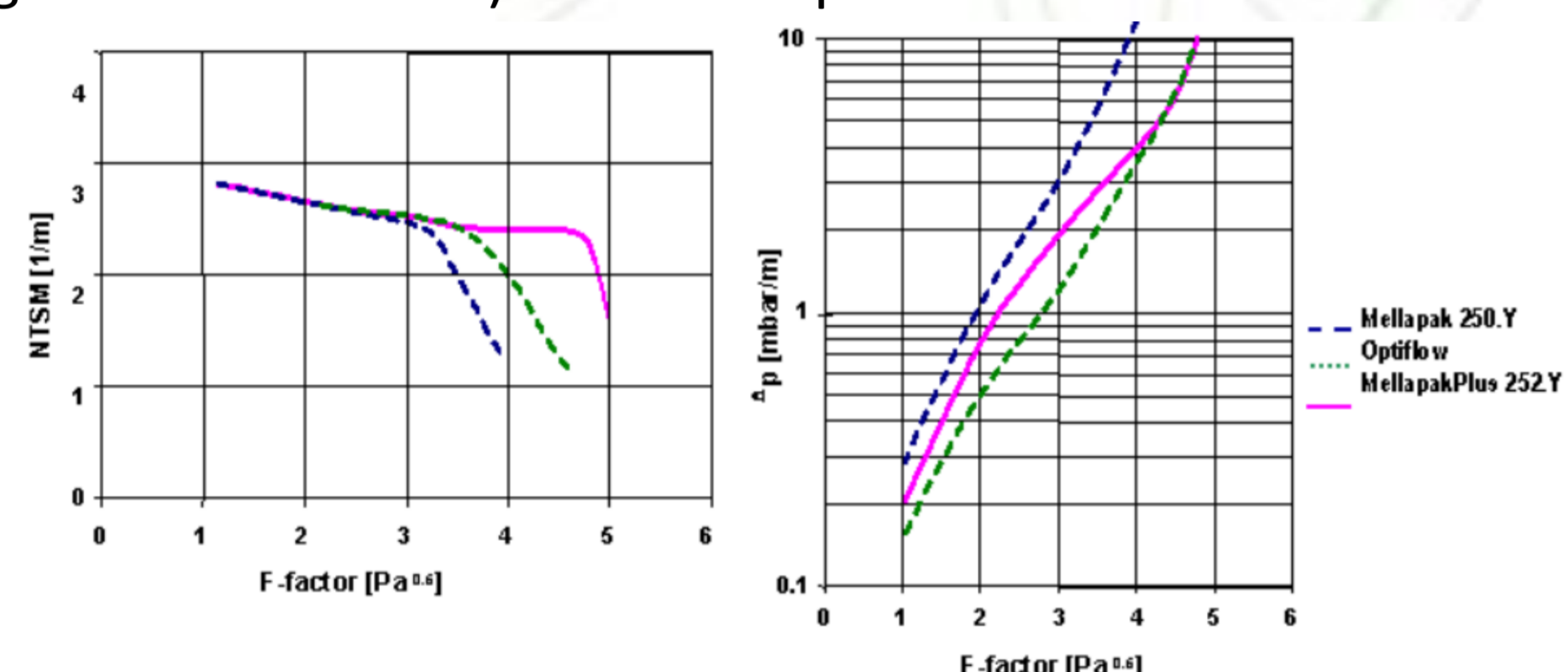
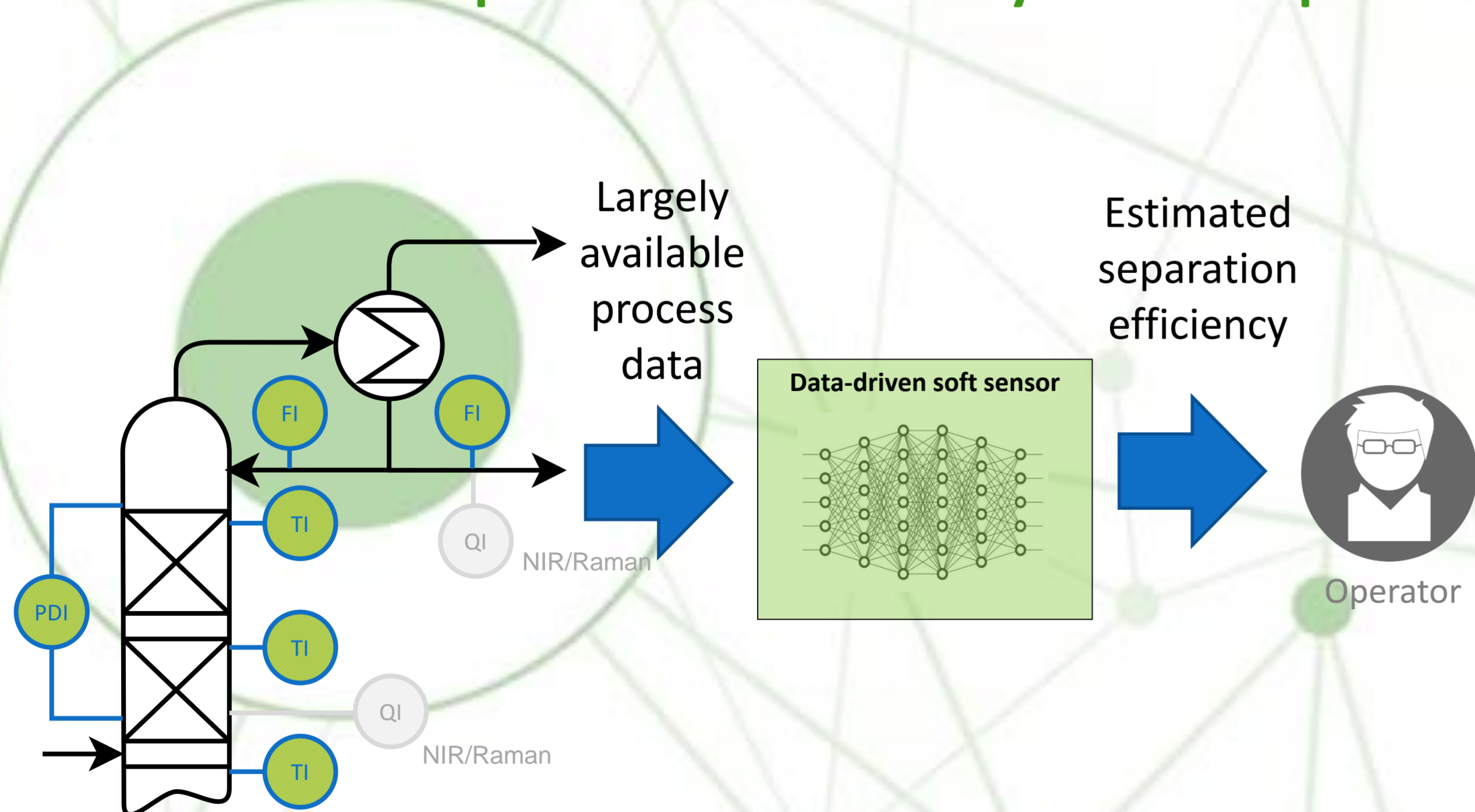$$\frac{\Delta p}{NTU_{OV}} Sc_V^{-\frac{2}{3}} = A \left(\frac{L}{V}\right)^n F_V^m$$

[2]

Various models for both dependencies are available. However, generalized pressure drop correlations are normally accurate to only within 20% [3].
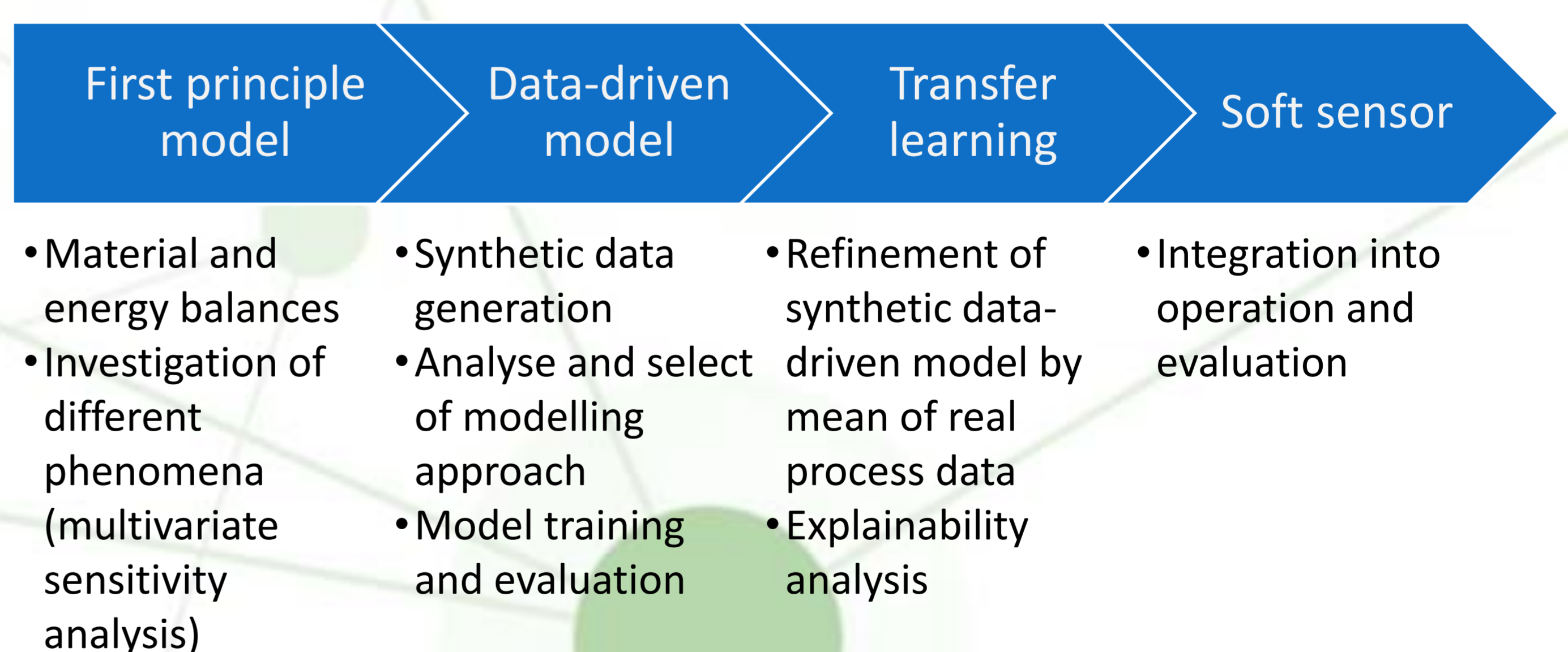
Transfer learning

(1) Generation of synthetic data based on empirical correlations

(2) Training a generic surrogate model based on synthetic data

(3) Fine tuning model to represent the real process

Synthetic data — Generic network — Generic separation efficiency

Real data — Specific network — Data-driven soft sensor — Specific separation efficiency

Show real separation efficiency to the operator

Largely available process data → Data-driven soft sensor → Estimated separation efficiency → Operator

Roadmap

First principle model	Data-driven model	Transfer learning	Soft sensor
• Material and energy balances • Investigation of different phenomena (multivariate sensitivity analysis)	• Synthetic data generation • Analyse and select of modelling approach • Model training and evaluation	• Refinement of synthetic data-driven model by mean of real process data • Explainability analysis	• Integration into operation and evaluation

[1] Spiegel, L., & Meier, W. (2003). Distillation columns with structured packings in the next decade. Chemical Engineering Research and Design, 81(1), 39–47. https://doi.org/10.1205/026387603321158177

[2] Billet, R. (2005). Packed towers: In processing and environmental technology. In Packed Towers: In Processing and Environmental Technology. https://doi.org/10.1002/3527605983

[3] HAT International. (2011). AlphaPACK® DESIGN SHEET - Random Packing.