Data-driven methodologies for large-scale implementation and roll-out

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CITIES
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Outline

Detecting house / household characteristics from measurements and weather data

- **Briefly about ENFOR**
- **Single house / household analyses**
- **Deployment on massive amounts of houses / households**
- **Harvesting additional information by comparing with background information**
- **Concluding remarks**

Forecasting and optimization software platform

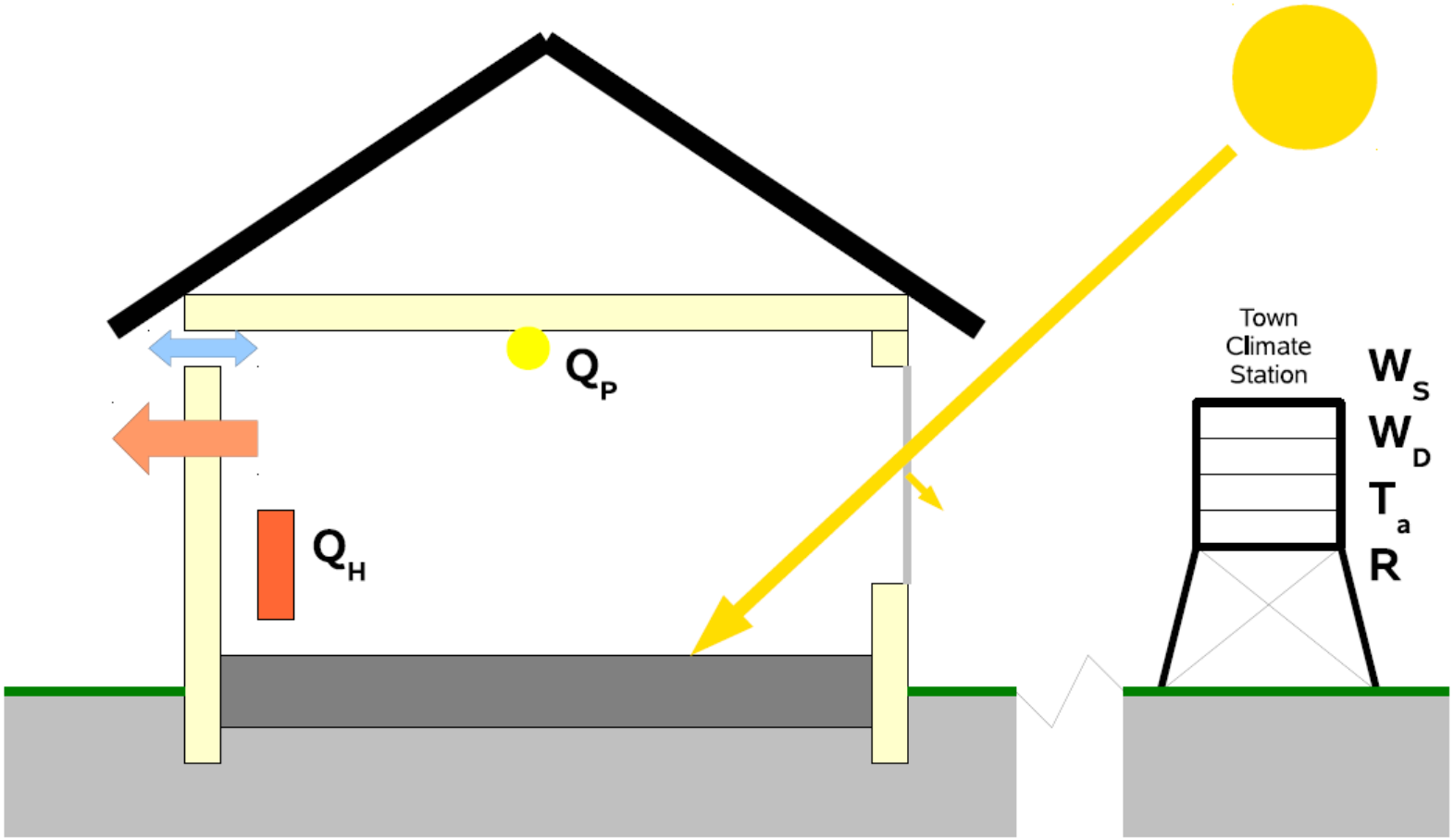
ENFOR solution portfolio

Software platform with a number of specialized solutions:

- *WindFor* - Forecasting of wind power
- *SolarFor* – Forecasting of solar power
- *LoadFor* – Forecasting of power load/demand
- *PMON* – Statistical quality control of the production from wind and solar farms
- *HeatFor* - Forecasting of heat demand
- *HeatTO* - Optimization of district heating networks
- *MetFor:* Locally optimized weather forecasts
- *PriceFor* – Forecasting of electricity prices
- *ChargeME* – Forecasting and charge management of electric vehicles
- *HydroFor* – Forecasting of hydro power production

Concept 1: Estimate building characteristics from data

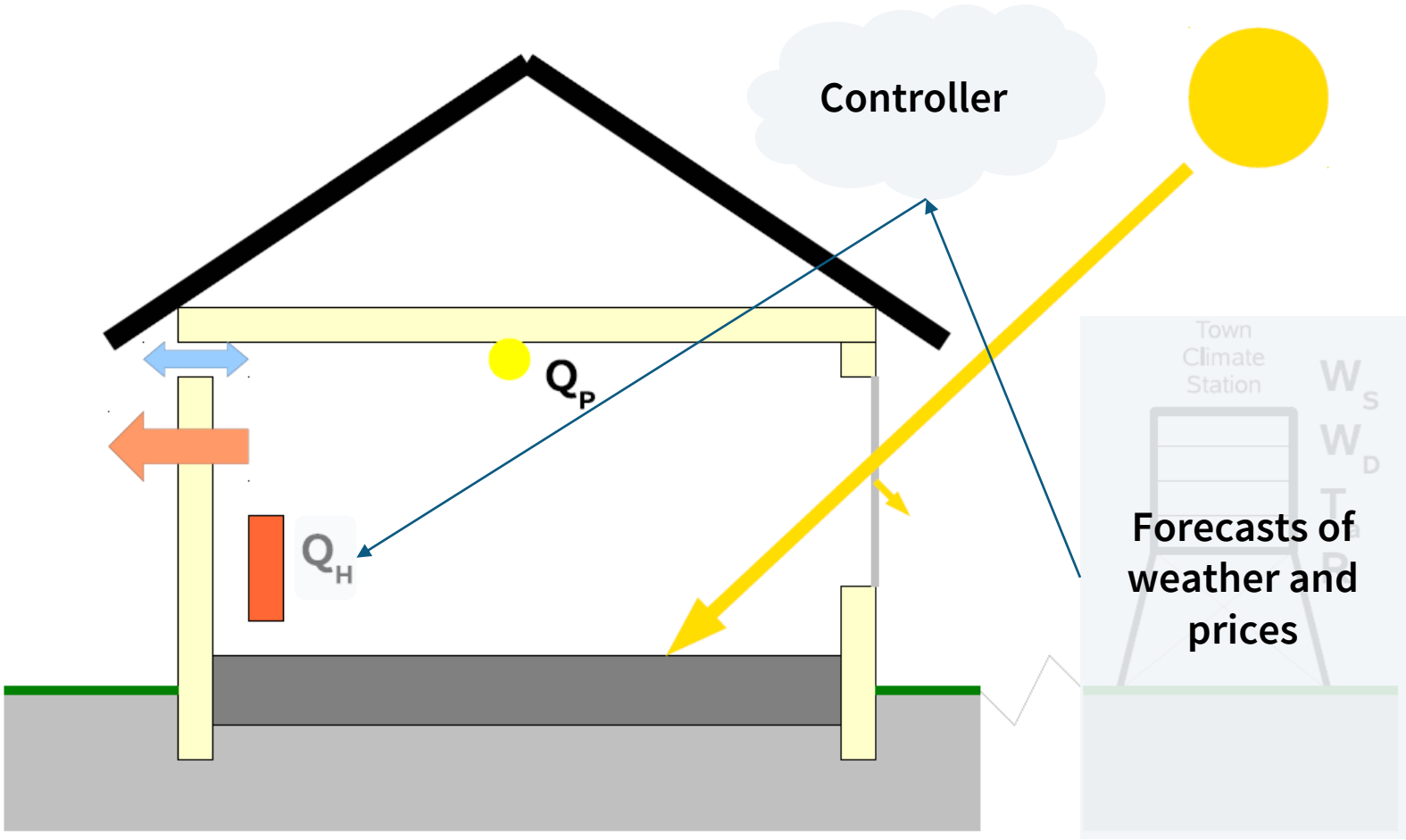
Simple model capturing main characteristics



Stig Bousgaard Mortensen & Henrik Aalborg Nielsen. *Analysis of energy consumption in single family houses.* DYNASTEE International workshop on Whole Building Testing, Evaluation and Modelling for Energy Assessment, 18-19 May 2011, Lyngby, Denmark.

Concept 2: Control the heating supplied to the building

Controller includes a model capturing main characteristics

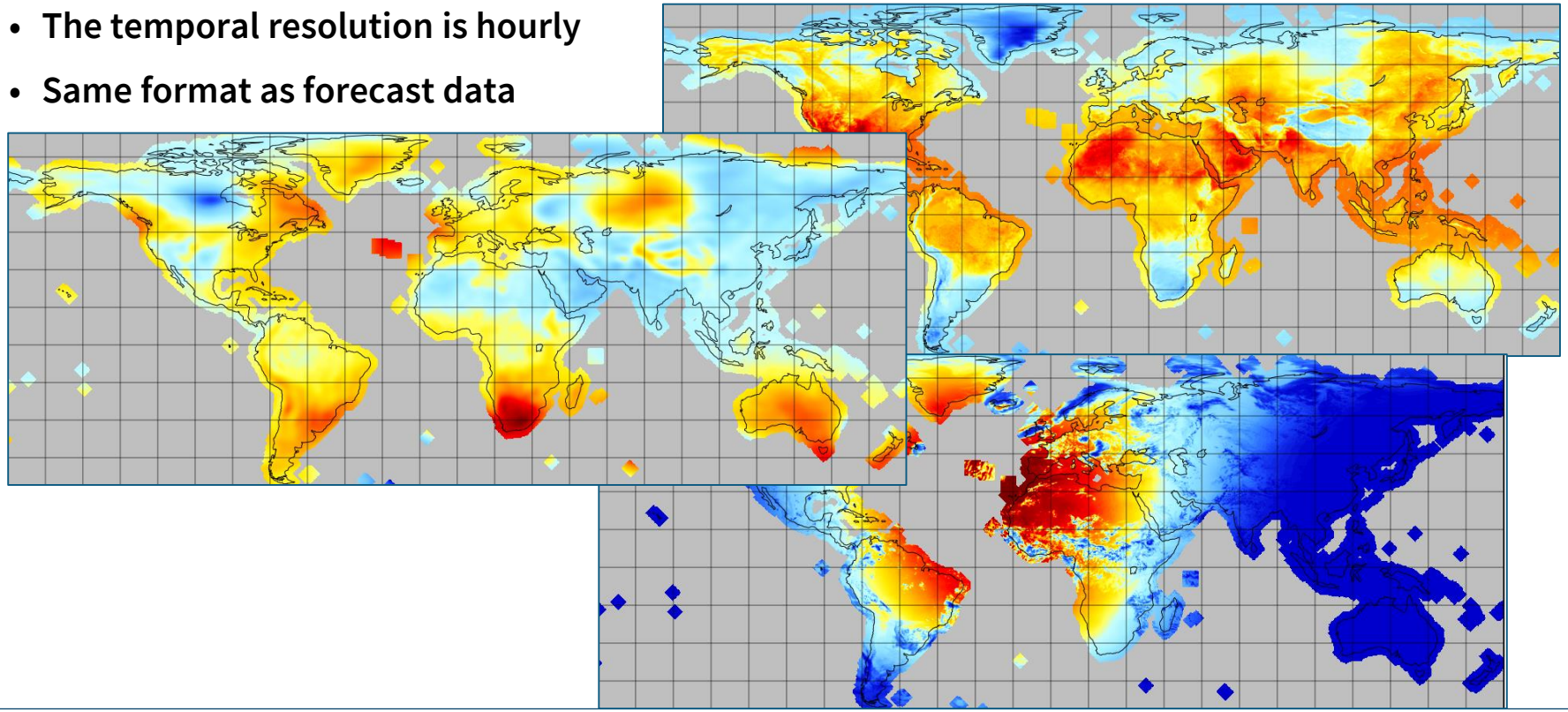


Sec. 6.3 of Madina, Carlos, et al. "Technologies and Protocols: The Experience of the Three SmartNet Pilots." Tso-Dso Interactions and Ancillary Services in Electricity Transmission and Distribution Networks, edited by Gianluigi Migliavacca, Springer, 2019, pp. 141–83, doi:10.1007/978-3-030-29203-4_6.

Climate data for every location

- or forecast data

- **ERA5-land available from Copernicus (European Union's Earth Observation Programme) Climate Data Store**
- **Surface data (temperatures of air and soil, wind, solar radiation, precipitation, …)**
- **The spatial resolution is 9 km**
- **The temporal resolution is hourly**
- **Same format as forecast data**



Analysis engine

- **Receives the energy consumption measurements and climate data**
- **Calculates / estimates energy characteristics on a per household basis**
- **Only the characteristics are stored together with an ID allowing the data to be linked with background information.**
- **Different analysis engines may supply different type of energy characteristics**

	UA W/°C	σ_{UA}	$\mathrm{gA}^{\max}$ W	$\mathrm{wA}_E^{\max}$ W/°C	$\mathrm{wA}_S^{\max}$ W/°C	$\mathrm{wA}_W^{\max}$ W/°C	T_i °C
4218598	211.8	10.4	597.0	11.0	3.3	8.9	23.6

How to scale up and harvest the benefit

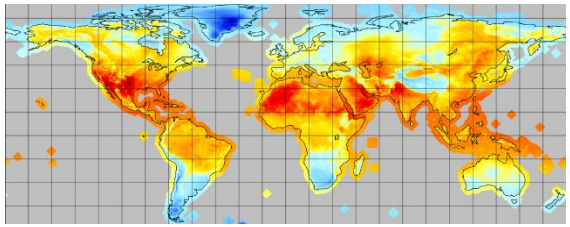
System overview

Measurements

Controller

Analysis Engine

Climate data / weather forecasts

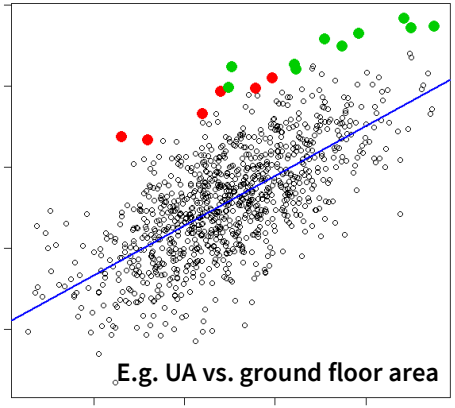


Synthesis (Machine Learning)

KPI DB

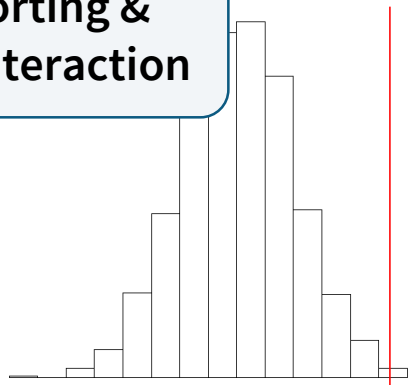
Background data interface (BBR etc.)

Reporting & user interaction



E.g. UA vs. ground floor area

	UA	σ_{UA}	gA^{max}	wA_E^{max}	wA_S^{max}	wA_W^{max}	T_i
	W/°C		W	W/°C	W/°C	W/°C	°C
4218598	211.8	10.4	597.0	11.0	3.3	8.9	23.6
4218600	98.7	10.8	-96.2	23.6	10.1	13.0	22.3
4381449	228.2	12.6	1012.3	29.8	42.8	39.7	19.4
4711160	155.4	6.3	518.8	14.5	4.4	9.1	22.5
4711176	178.5	7.3	800.0	1.9	-7.6	8.5	26.4
4836681	155.3	8.1	591.0	39.5	28.0	21.4	23.5
4836722	236.0	17.7	1578.3	4.3	3.3	18.9	23.5
4986050	159.6	10.7	715.7	10.2	7.5	7.2	20.8
5069878	144.8	10.4	87.6	3.7	1.6	17.3	21.8
5069913	207.8	9.0	962.5	3.7	8.6	10.6	22.6
5107720	189.4	15.4	657.7	41.4	29.4	16.5	21.0

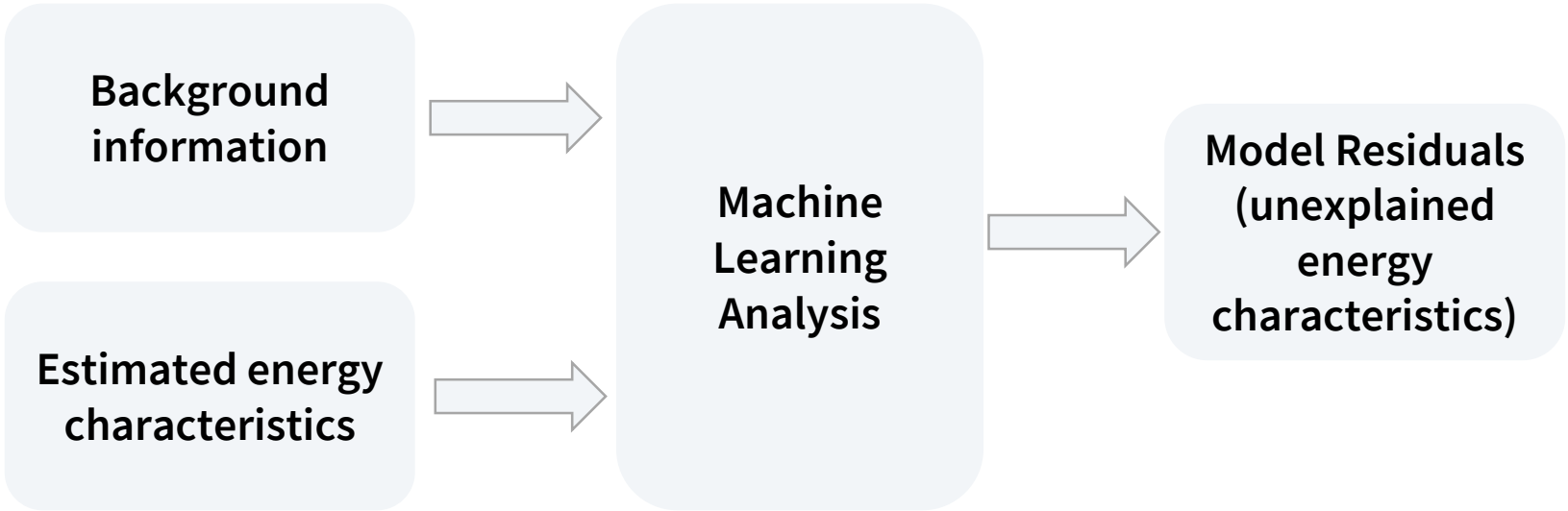


E.g. distribution of UA residuals across houses

Synthesis

Machine learning analysis linking houses / apartments / households to background information

- **Find the best possible mapping from background information to energy consumption characteristics**
- **The part which cannot be explained by the mapping is the interesting houses / apartments / households, because this points towards entities with unusual good or bad energy performance**



Data base

- One part of the data base contain the results from the analysis engine (example right)
- An other part of the data base contain the house / apartment / household background information
- Yet an other part of the data base contain the machine learning analysis model errors (model residuals)

Analysis engine results

Background information

Analysis model residuals

	UA W/°C	σ_{UA}	gA^{max} W	wA_E^{max} W/°C	wA_S^{max} W/°C	wA_W^{max} W/°C	T_i °C
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5107720	189.4	15.4	657.7	41.4	29.4	16.5	21.0
5127784	264.7	16.6	1364.5	18.4	-10.0	-20.0	27.0
5159799	204.8	5.5	614.2	-1.9	-2.9	3.9	26.0
5164474	173.4	14.3	68.4	8.2	8.2	-4.8	23.4
5164485	196.2	6.6	931.3	14.6	23.8	30.6	22.6
5164523	148.3	8.5	758.1	-6.9	1.1	7.0	26.0
5168264	169.6	7.7	554.1	25.8	8.4	2.1	21.7
5183206	177.7	14.3	429.0	-4.3	-26.2	5.6	24.2
5183228	208.9	7.8	724.7	23.1	19.4	31.9	21.6
5183232	128.8	14.6	608.7	18.4	2.5	8.4	25.0
5191179	63.3	5.4	186.9	0.3	-1.1	0.4	50.0
5194940	221.5	13.2	246.3	8.0	2.1	30.5	17.5
5194965	132.3	9.6	407.5	-7.4	-2.4	7.3	26.5
5197381	182.3	13.9	1038.8	31.6	19.7	23.5	24.4
5223030	206.2	17.8	841.3	6.3	-42.1	-8.7	27.3
5223036	171.4	15.2	522.3	2.8	-6.5	12.7	22.7

Concluding remarks

System characteristics

- Modular design where individual components can be replaced / updated
- Analysis engine can run the analyses for the individual households in parallel and can therefore easily be scaled
- The machine learning based synthesis works only on KPI's and background information and can therefore handle millions of households with standard technologies. Big data technologies can be applied if required
- Reporting select houses / households with unusual model residuals
- Via user interaction it will be possible to gather additional information (see aforementioned DYNASTEE paper).

Thank you for your attention!

Questions:

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