SVEUČILIŠTE U ZAGREBU
Fakultet elektrotehnike i računarstva

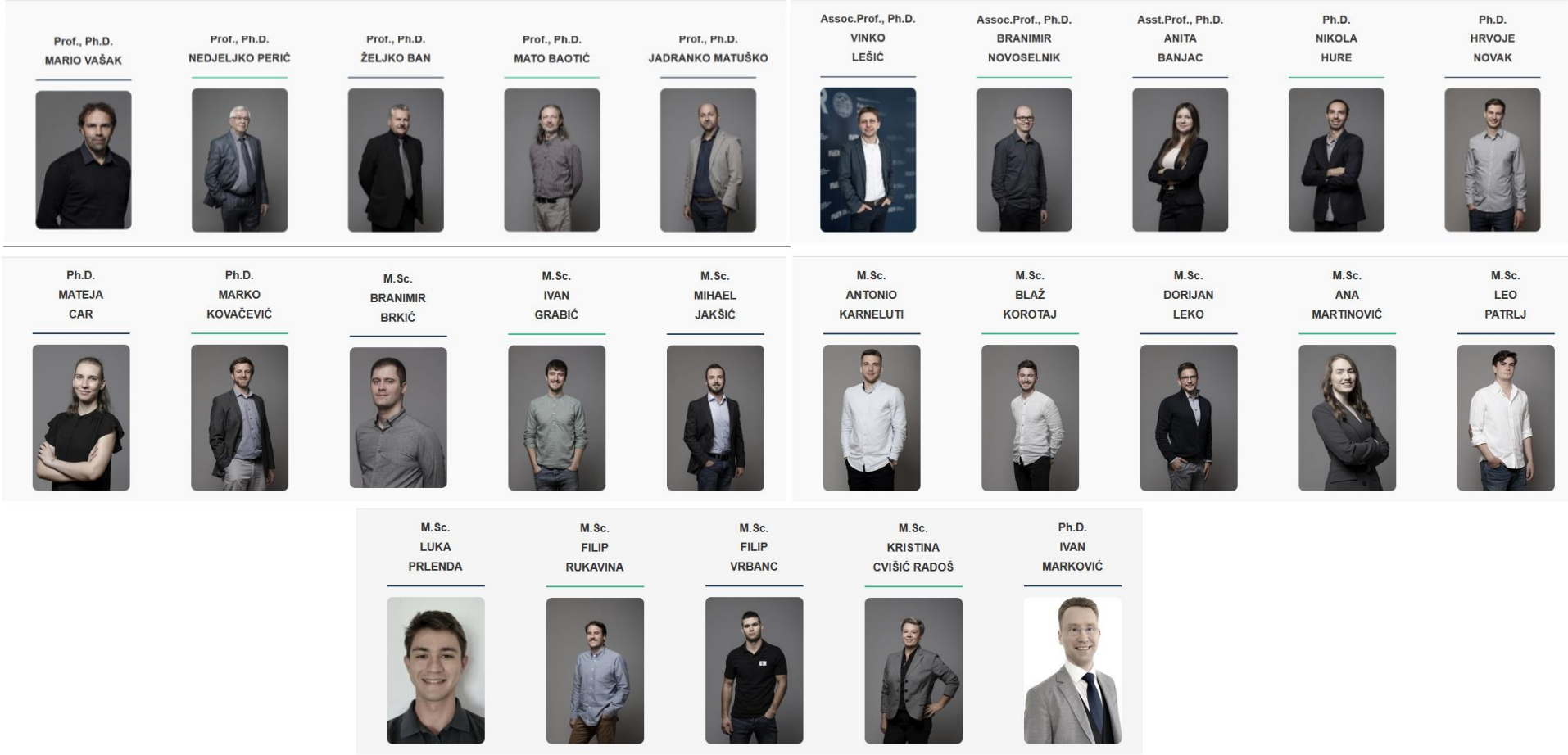
LARES
Laboratorij za sustave obnovljivih izvora energije

Laboratorij za sustave obnovljivih izvora energije

Studij Informacijska i komunikacijska tehnologija

Profil Automatika i robotika

LARES tim


Prof., Ph.D.
MARIO VAŠAK
Prof., Ph.D.
NEDJELJKO PERIĆ
Prof., Ph.D.
ŽELJKO BAN
Prof., Ph.D.
MATO BAOTIĆ
Prof., Ph.D.
JADRANKO MATUŠKO
Assoc.Prof., Ph.D.
VINKO
LEŠIĆ
Assoc.Prof., Ph.D.
BRANIMIR
NOVOSELNIK
Asst.Prof., Ph.D.
ANITA
BANJAC
Ph.D.
NIKOLA
HURE
Ph.D.
HRVOJE
NOVAK
Ph.D.
MATEJA
CAR
Ph.D.
MARKO
KOVAČEVIĆ
M.Sc.
BRANIMIR
BRKIĆ
M.Sc.
IVAN
GRABIĆ
M.Sc.
MIHAEL
JAKŠIĆ
M.Sc.
ANTONIO
KARNELUTI
M.Sc.
BLAŽ
KOROTAJ
M.Sc.
DORIJAN
LEKO
M.Sc.
ANA
MARTINOVIĆ
M.Sc.
LEO
PATRLJ
M.Sc.
LUKA
PRLENDA
M.Sc.
FILIP
RUKAVINA
M.Sc.
FILIP
VRBANC
M.Sc.
KRISTINA
CVIŠIĆ RADOŠ
Ph.D.
IVAN
MARKOVIĆ

LARES: Umjetna inteligencija u tehničkim sustavima

Dinamički sustavi

Računalno odlučivanje optimizacijom

Znanje + podatci

LARES: Tehnički sustavi za energetsku tranziciju

Programski moduli

MODELIRANJE → PREDVIĐANJE → UPRAVLJANJE

A. **Optimalna parametrizacija** (npr. veličina fotonaponskog sustava i baterijske pohrane za zgradu?)

B. **Kratkoročno planiranje** (npr. kakav profil crpljenja vode u vodospreme primijeniti i koju fleksibilnost ponuditi?)

C. **Online rad** u stvarnom vremenu (tj. kako djelovati sada uvažavajući trenutna stanja, zahtjeve, obaveze i predviđanja?)

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PAMETNE ZGRADE – više od automatizacije

doc. dr. sc. Anita Banjac

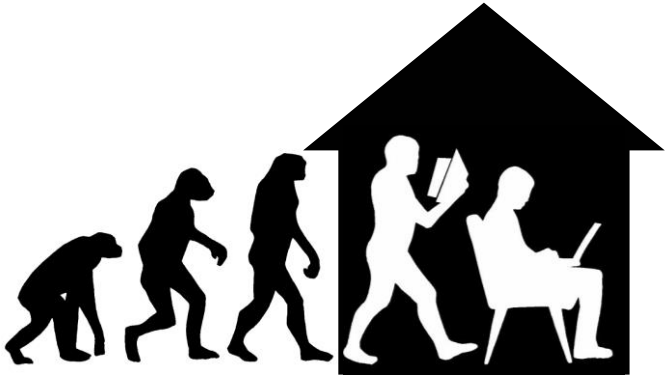
Zašto zgrade?

U PROSJEKU PROVODIMO

90%

NAŠEG VREMENA

U ZATVORENOM PROSTORU



The Indoor Generation

European Commission (2003) - Indoor air pollution: new EU research reveals higher risk than previously thought

Zgrada nije samo prostor!

PODACI

Nevidljiva valuta pametnih zgrada

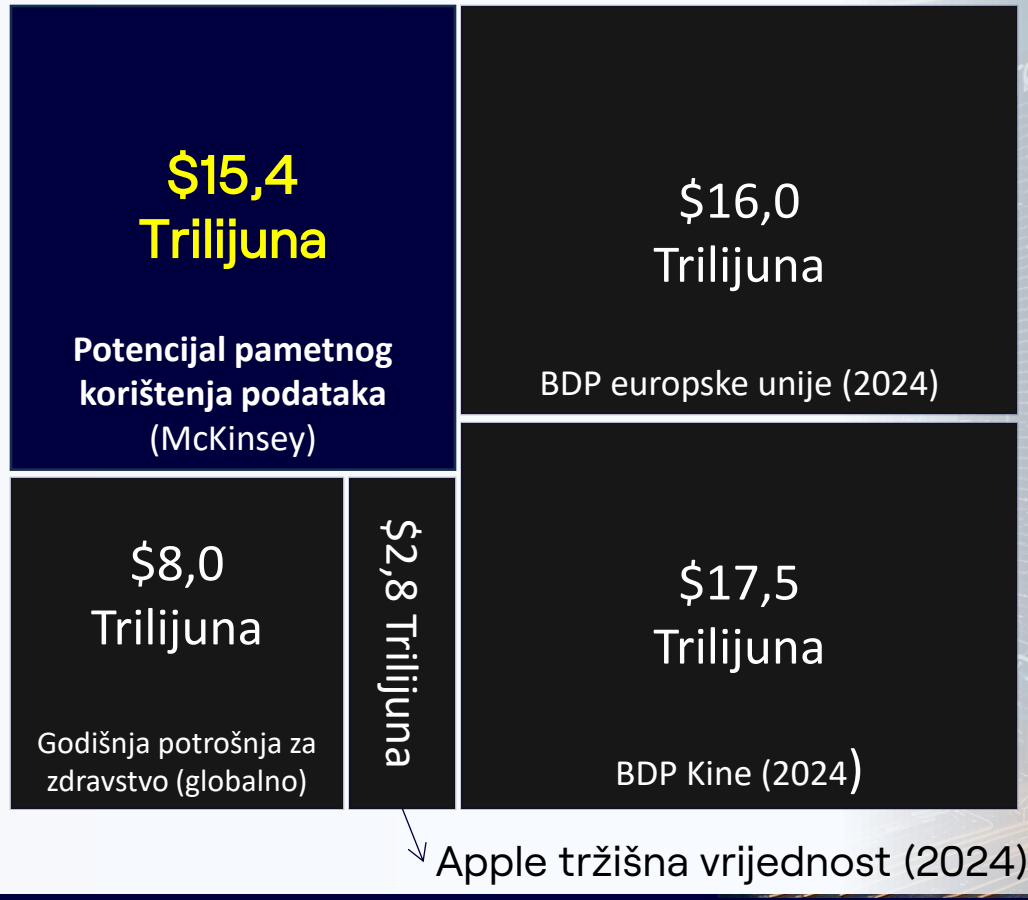
Podaci – skrivena valuta u zgradama

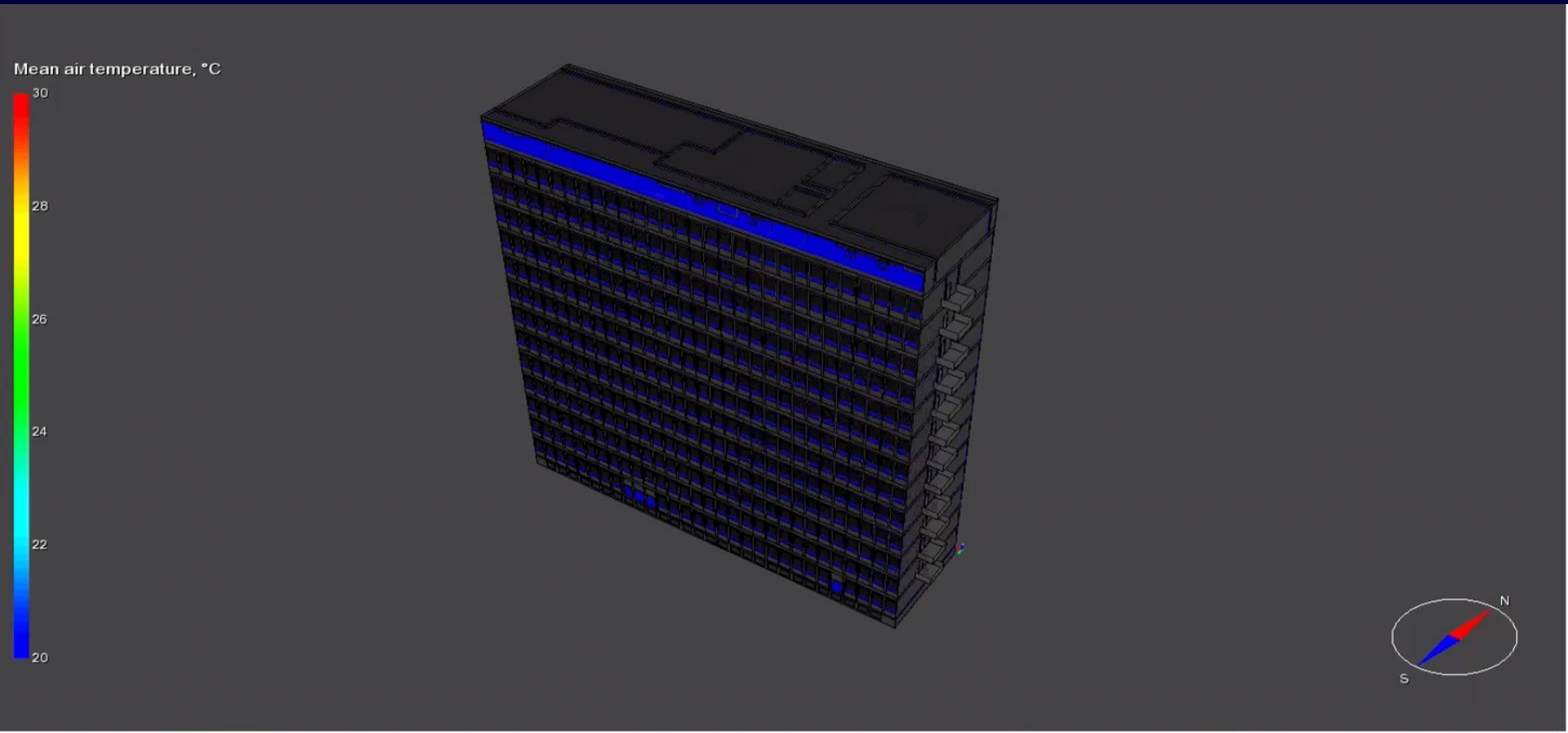
$15,4 Trilijuna

Potencijal pametnog korištenja podataka
(McKinsey)

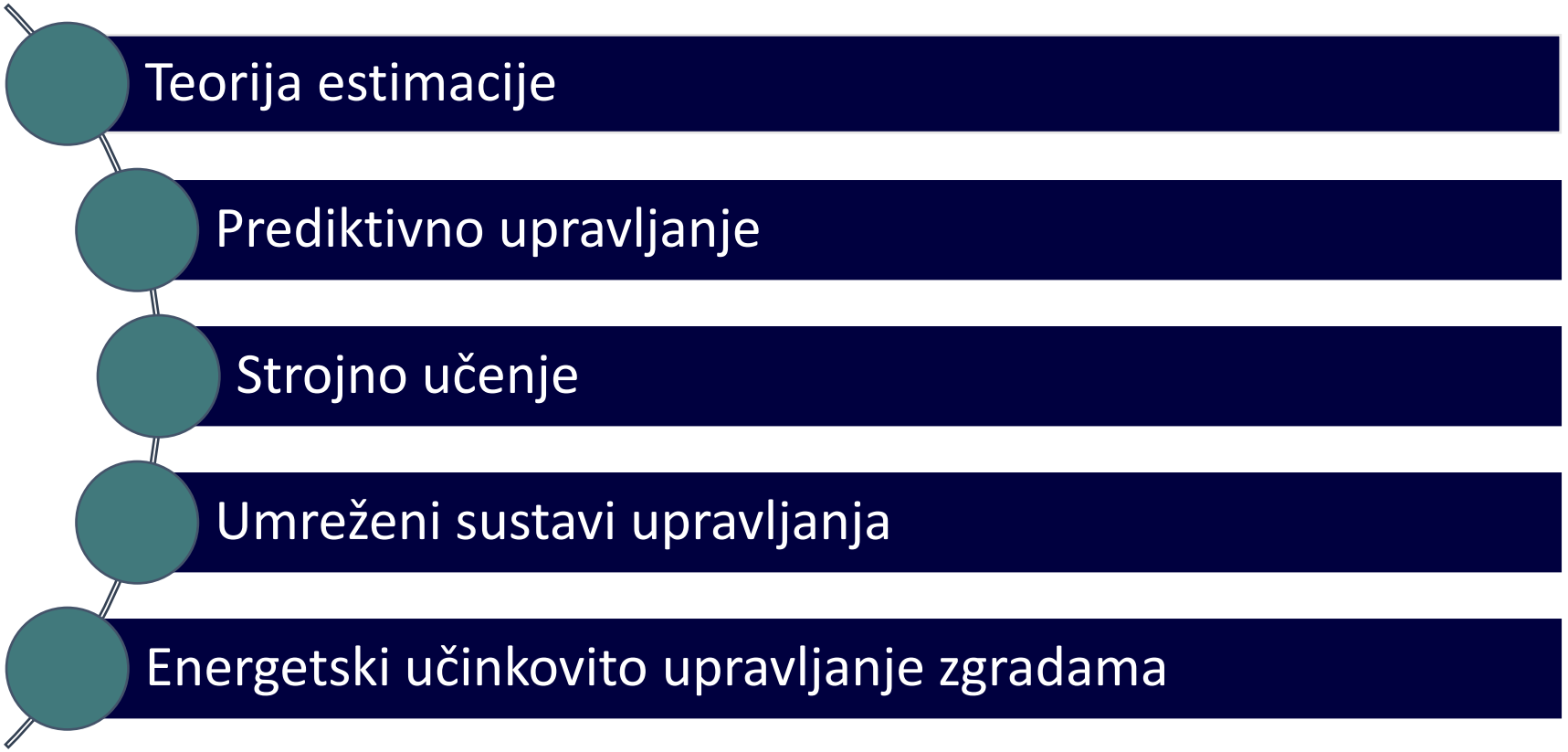
LINK: https://modbs.co.uk/news/fullstory.php/aid/20085/Putting_the_value_on_data_in_smart_buildings_.html

Podaci – skrivena valuta u zgradama




Mean air temperature, °C
30
28
26
24
22
20
N
S
x+
x-
y+
y-
z+
z-
Show...
Lock...
Animation
Animation
Close
Speed (hours/s)
4.0
00:00:00
2017-05-01
Mon

AiR kolegiji i pametne zgrade



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Kritična infrastruktura – optimalna podrška u vođenju

dr. sc. Nikola Hure

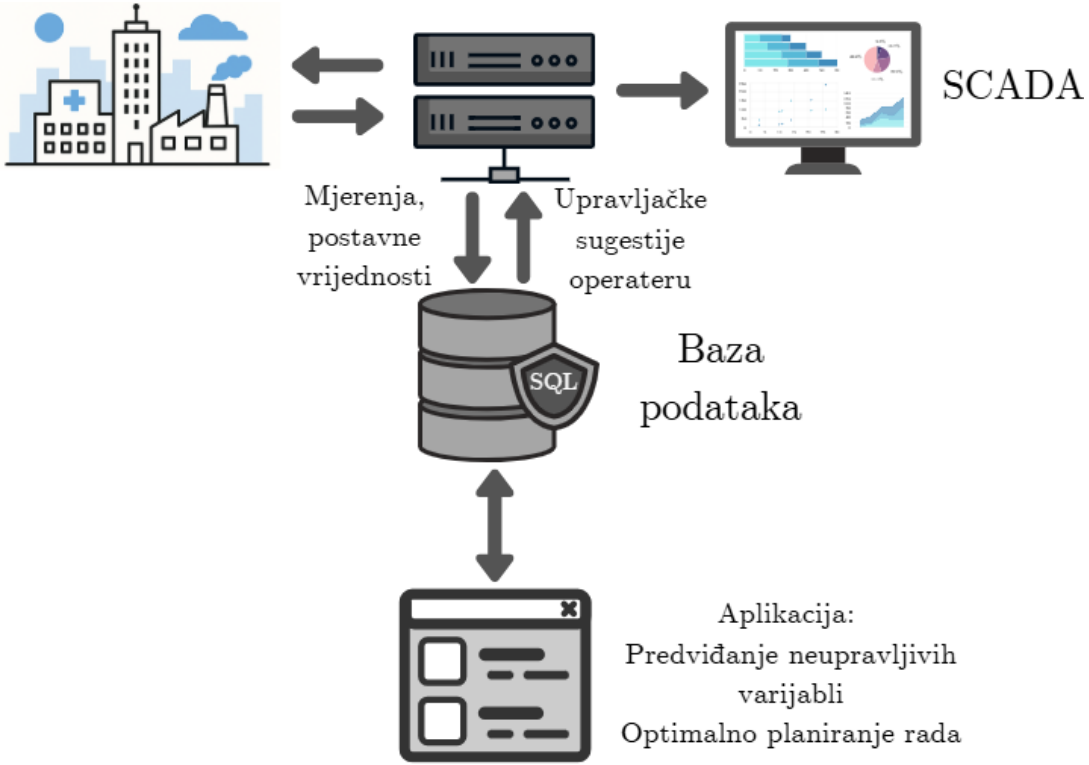
Kritična infrastruktura (KI)

- Uključuje infrastrukturu ključnu za funkcioniranje društva i ekonomije
  - Pitka voda
  - Transport
  - Elektroenergetski sustav i dr.
- Složeni sustavi, često spregnuti
  - Nužan pouzdan model sustava
  - Uključuje i neupravljive varijable: ponašanje društva (promet, voda) - modeli strojnog učenja
  - Puna efikasnost sustava ostvaruje se upravljanjem sustavom kao cjelinom
- Otpornost KI na ekstremne događaje i sigurnosne prijetnje:
  - Optimalna podrška u odlučivanju

Čovjek ju je stvorio, ali još nije sasvim njom ovladao.

KI – optimalna podrška u odlučivanju

- Podrška u odlučivanju zasnovana na umjetnoj inteligenciji



Funded by the European Union
NextGenerationEU

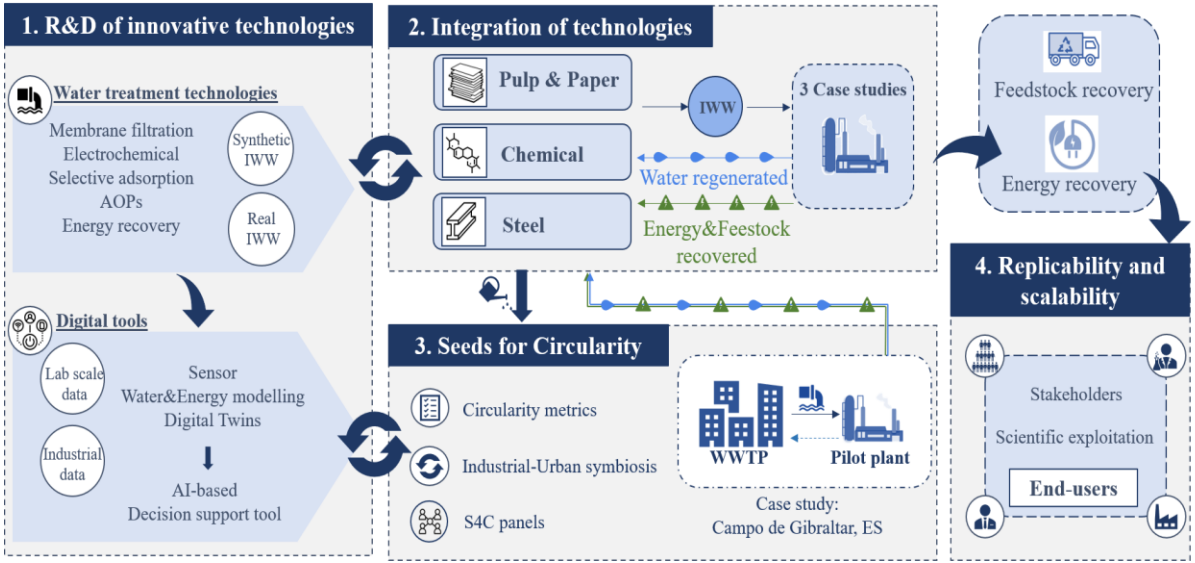
Dodola

REwaise
Resilient Water Innovation for Smart Economy

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 869496

KI – industrija

- Postrojenja za preradu otpadnih voda iz industrije

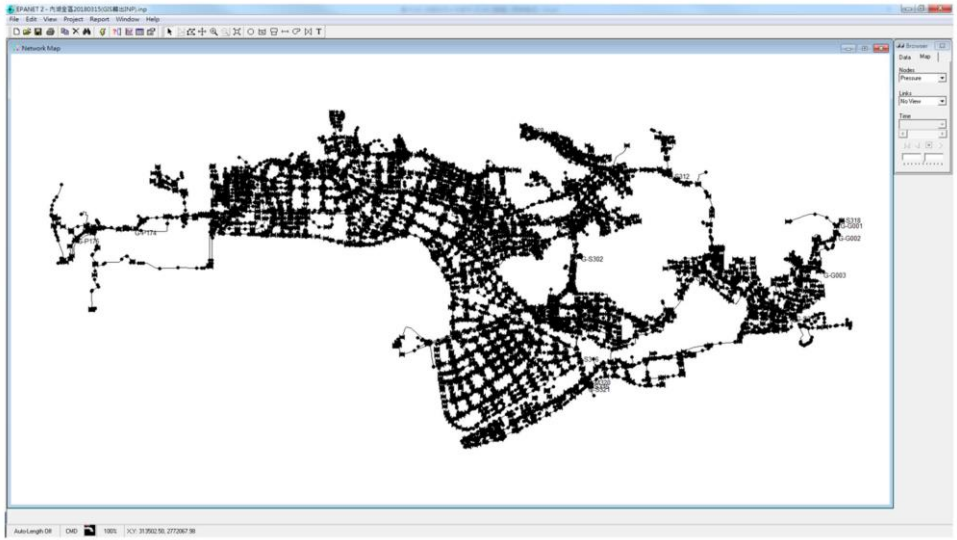


This Project has received funding from the European Union's Horizon Research and Innovation Programme under Grant Agreement N. 101138097

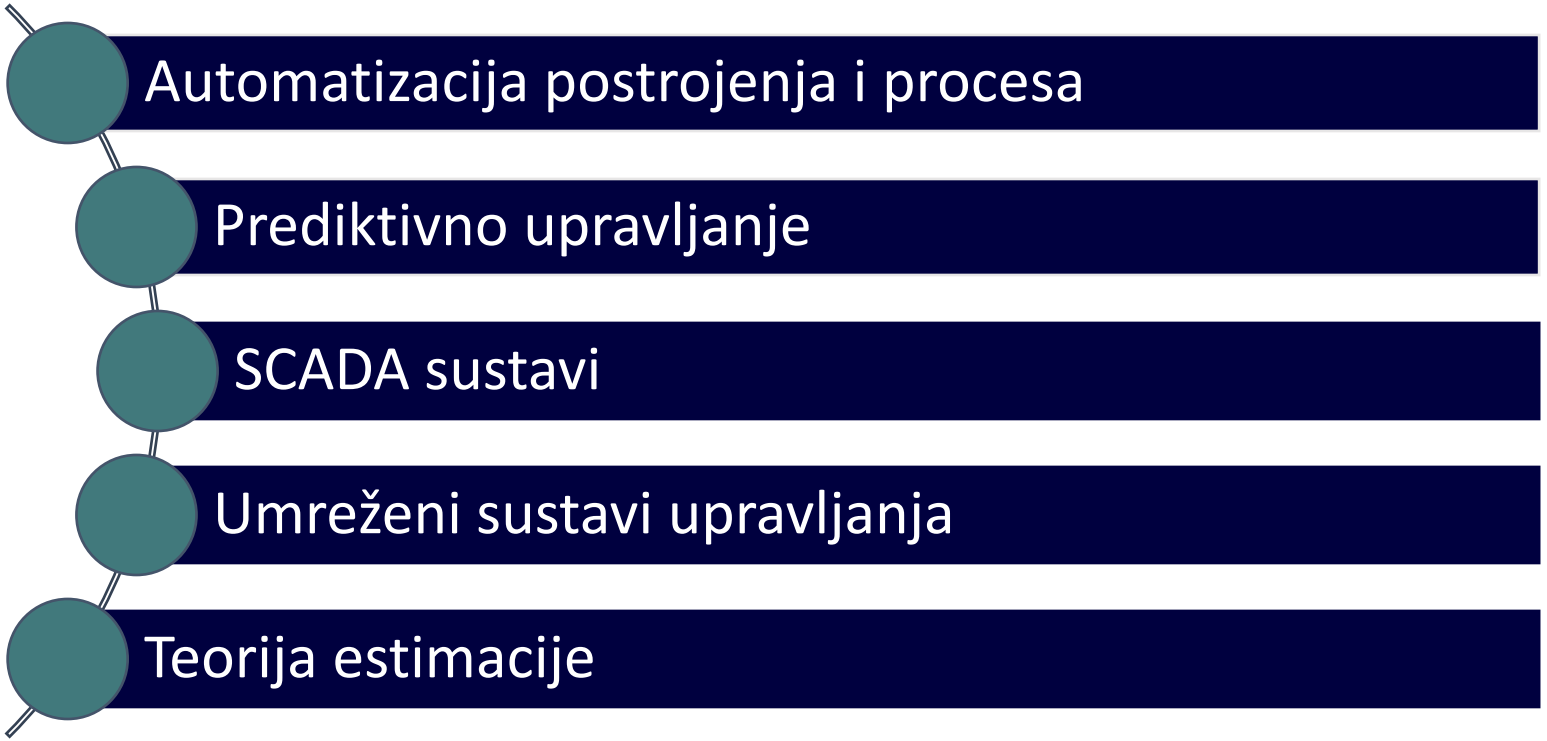
Primjer: vodoopskrba

- Zadatak:
  - Dan-unaprijed podrška u vođenju za gradsku vodoopskrbnu mrežu (10 vodosprema, 8 ventila, 9 pumpi, **7363** cijevi i **6992** čvorova)
  - Optimalno vođenje za smanjenje operativnog troška (uz sva fizikalna ograničenja)
- Rezultati:
  - Smanjenje troškova u iznosu **39%**

	Trošak vodnih gubitaka [EUR]	Trošak el. energije [EUR]	Ukupni trošak [EUR]
Standardno	18286	4390	22676
Optimalno	10584	3320	13904



AiR kolegiji i kritična infrastruktura



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Napredne punionice lakih el. vozila za pametni grad

prof. dr. sc. Željko Ban
(prof. dr. sc. Mario Vašak)

Napredne punionice lakih el. vozila za pametni grad

- Punionice lakih električnih vozila
  - Mikromreža
    - Fotonaponski sustav
    - Veza prema sustavu pohrane u stanici
    - Veza prema gradskoj električnoj mreži
  - Upravljivi sustav punjenja baterije bicikla
    - Identifikacija tipa baterije
      - Estimacija stanja napunjenosti
  - SCADA sustav za upravljanje grupom punionica
    - Identifikacija korisnika
    - Statistika korištenja
    - Upravljanje svim sustavima punionica
  - Sustav video nadzora
  - Reklamni video sustav
    - Identifikacija dobi i spola osobe ispred punionice
    - Podešavanje tipa reklame

Upravljanje tokovima energije

Identifikacija modela
Estimacija parametara
Strojno učenje

Sigurnosni sustavi
Sustavi komunikacije

Obrada 3D slike u realnom vremenu
Sustavi prepoznavanja

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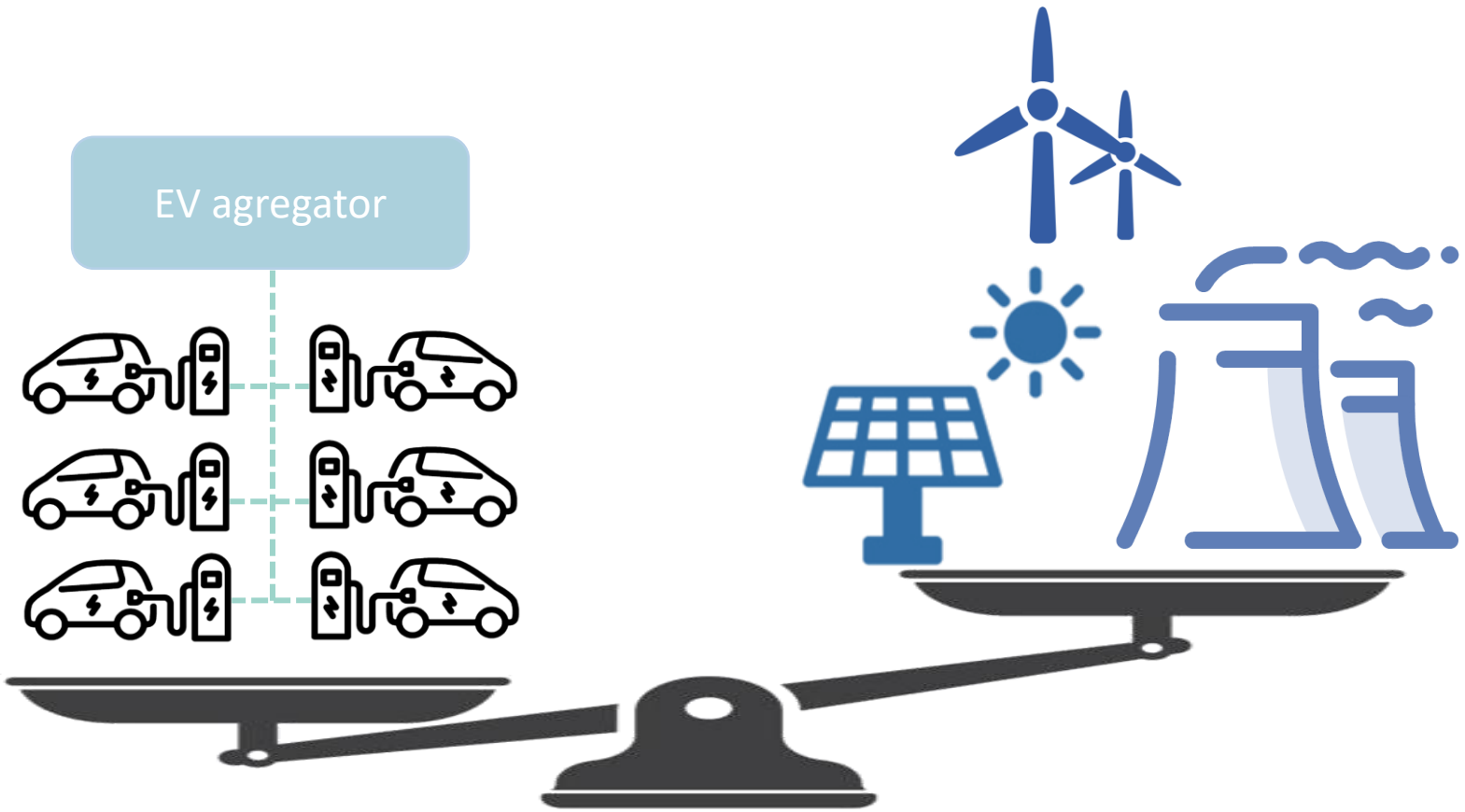
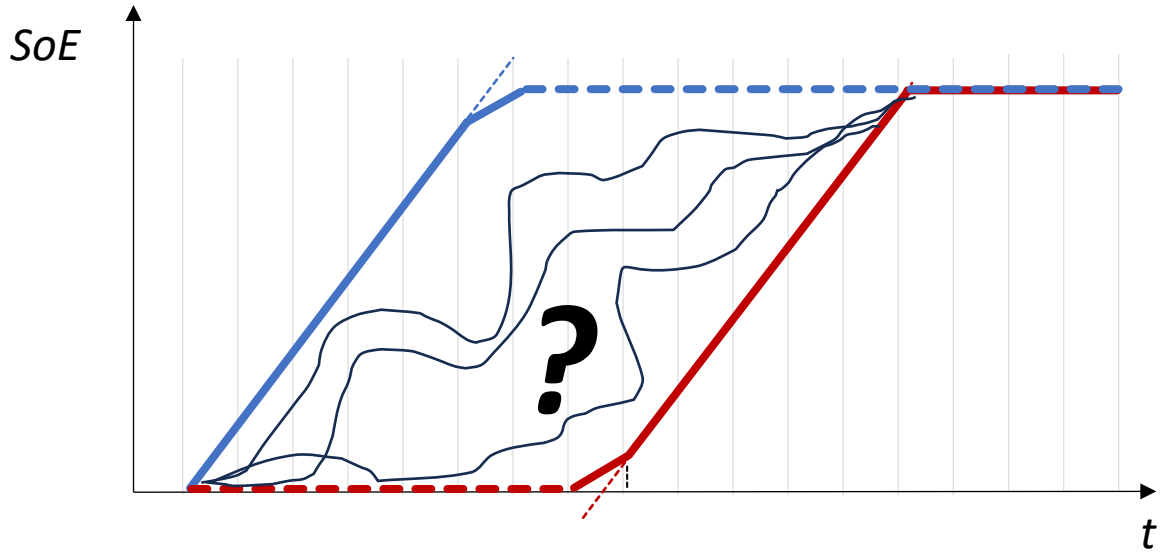
Planiranje punjenja el. vozila

dr. sc. Marko Kovačević

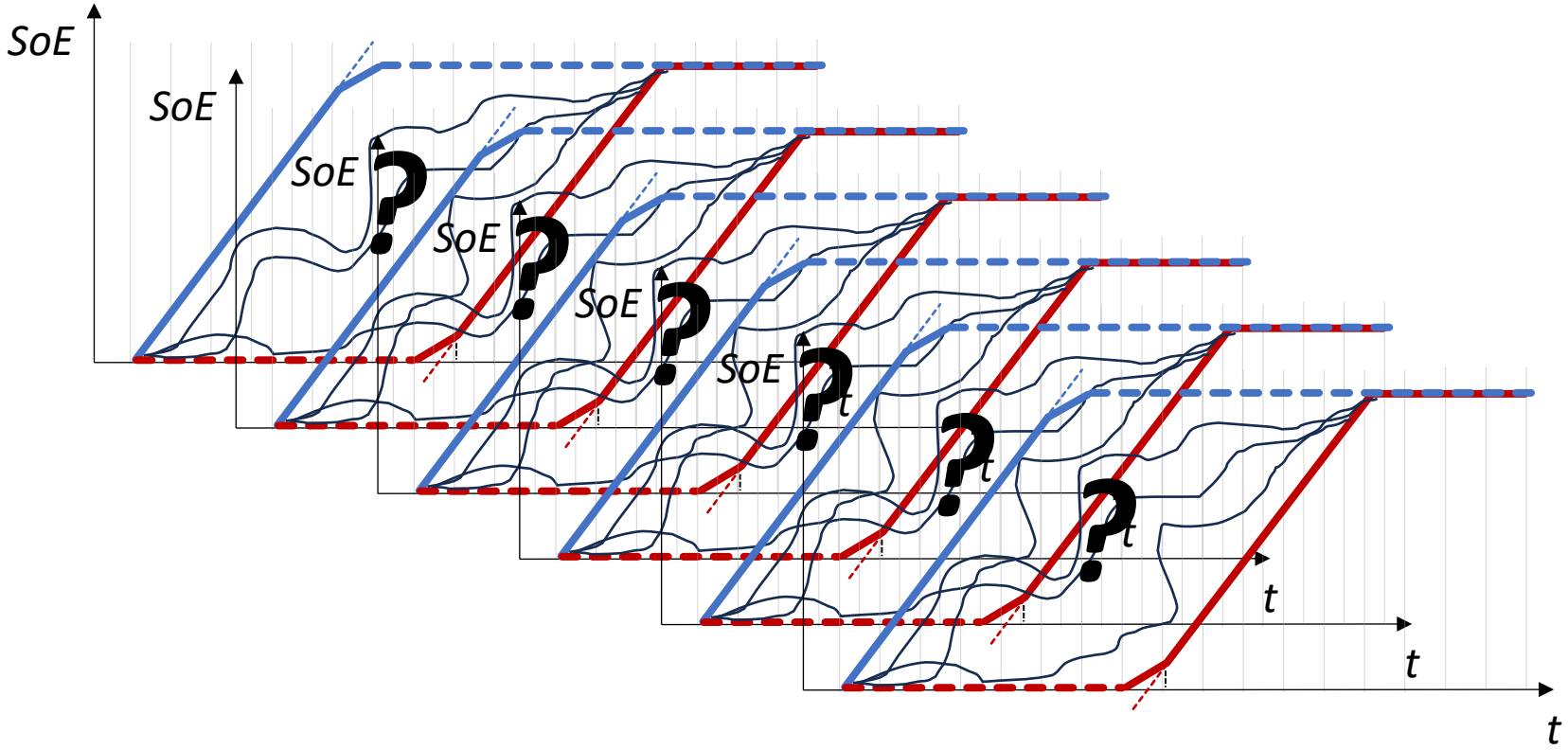
Planiranje punjenja električnih vozila



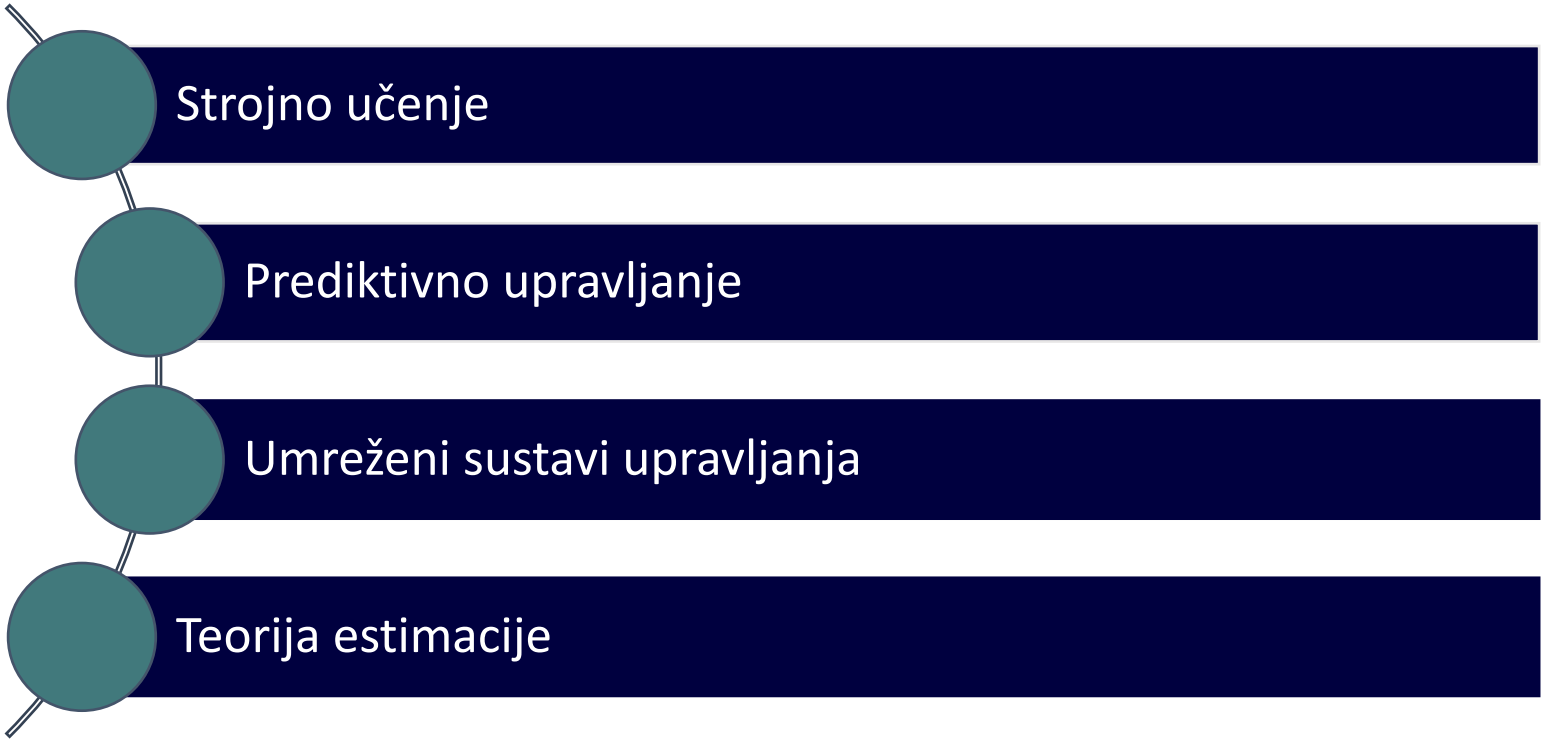
Planiranje punjenja električnih vozila



Planiranje punjenja električnih vozila



AiR kolegiji i pametno punjenje EV-a



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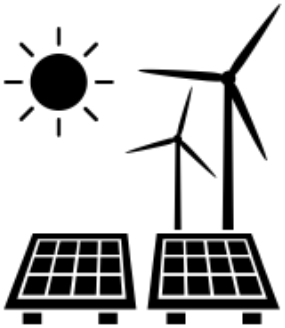
Združeno optimiranje za energetska čvorišta

Antonio Karneluti, mag. ing.

Združeno optimiranje za energetska čvorišta



Električna energija

Toplinska energija

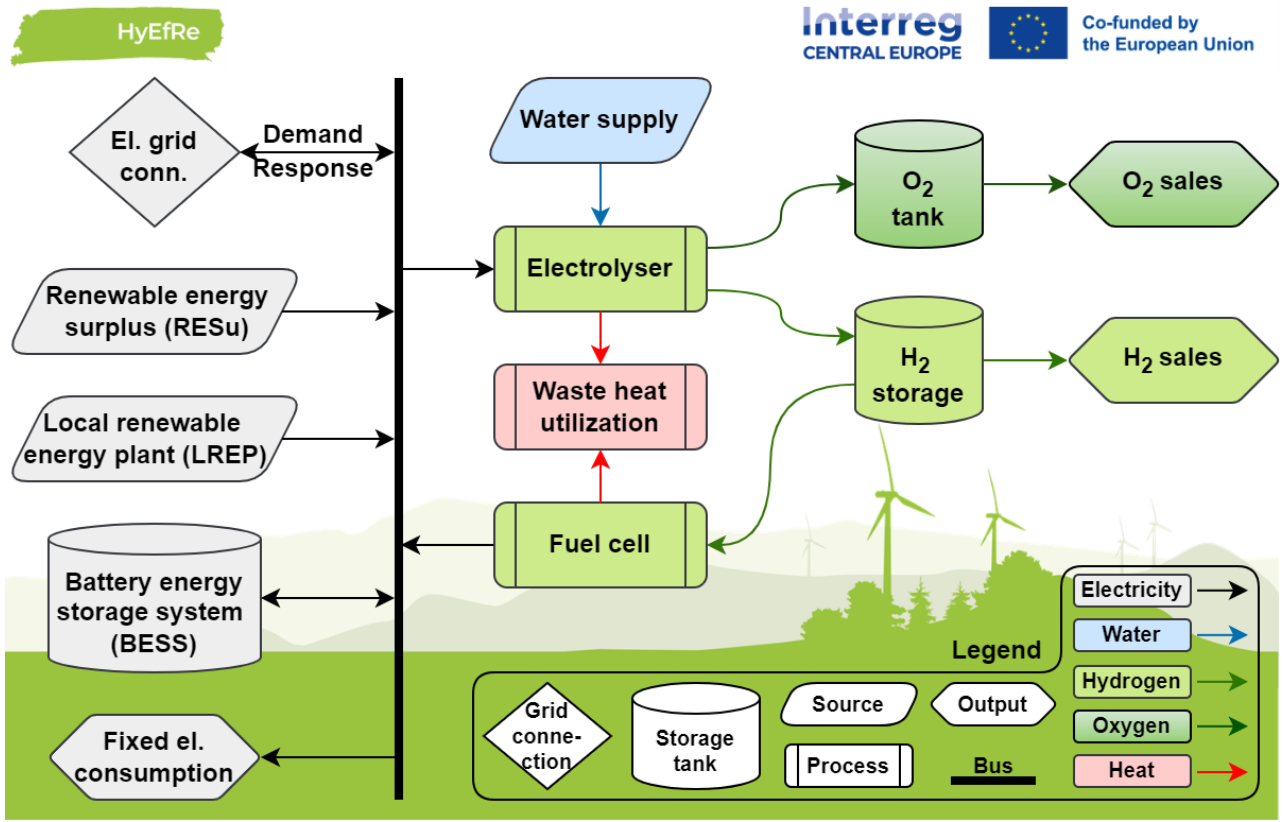
Energetsko čvorište

Prirodni plin

Voda

Vodik, kisik

Združeno optimiranje za energetska čvorišta



Kako najbolje iskoristiti višak obnovljive energije?

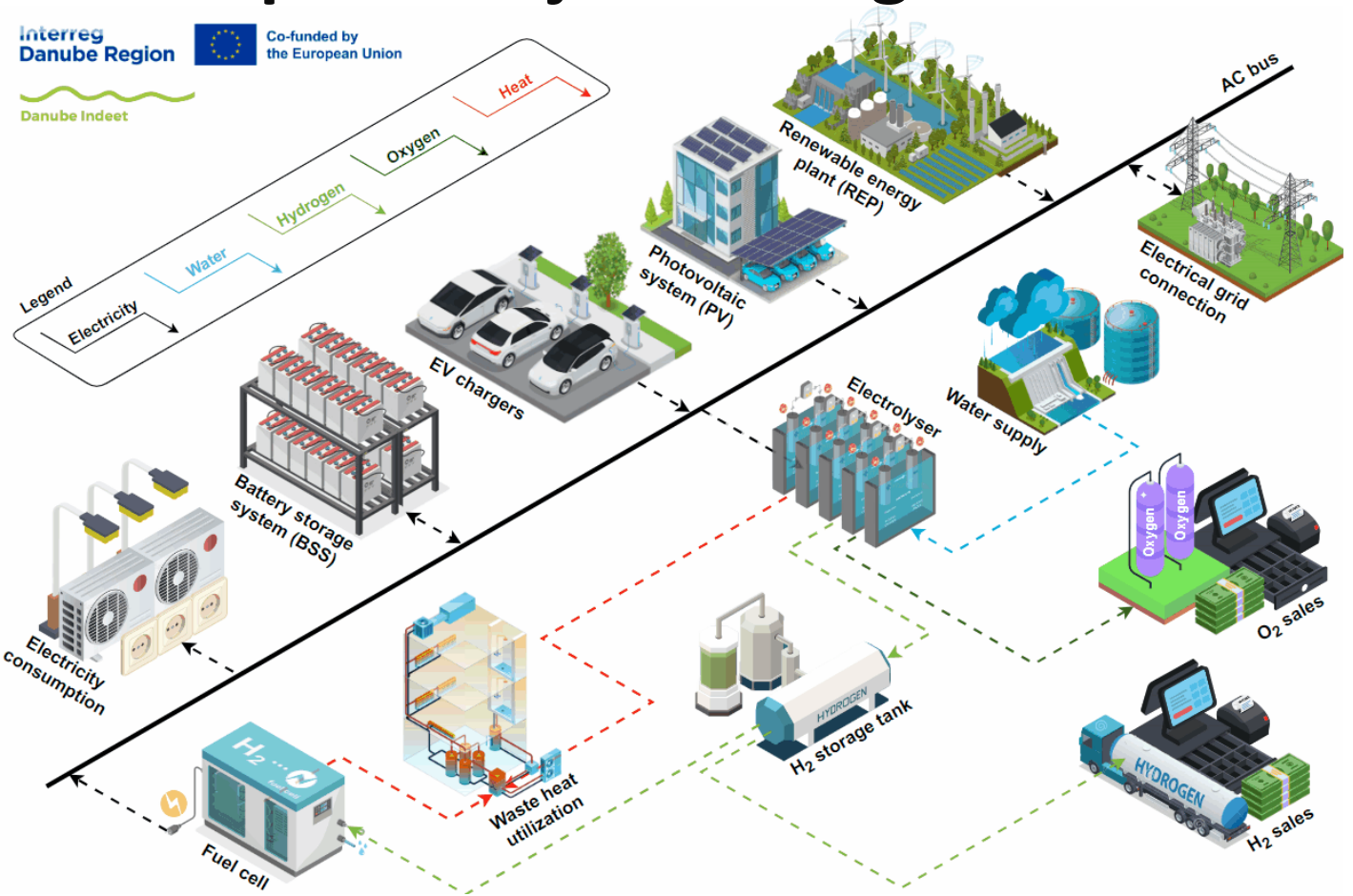
Koliko košta ukupna investicija?

Koliko €€€ mogu zaraditi godišnje?

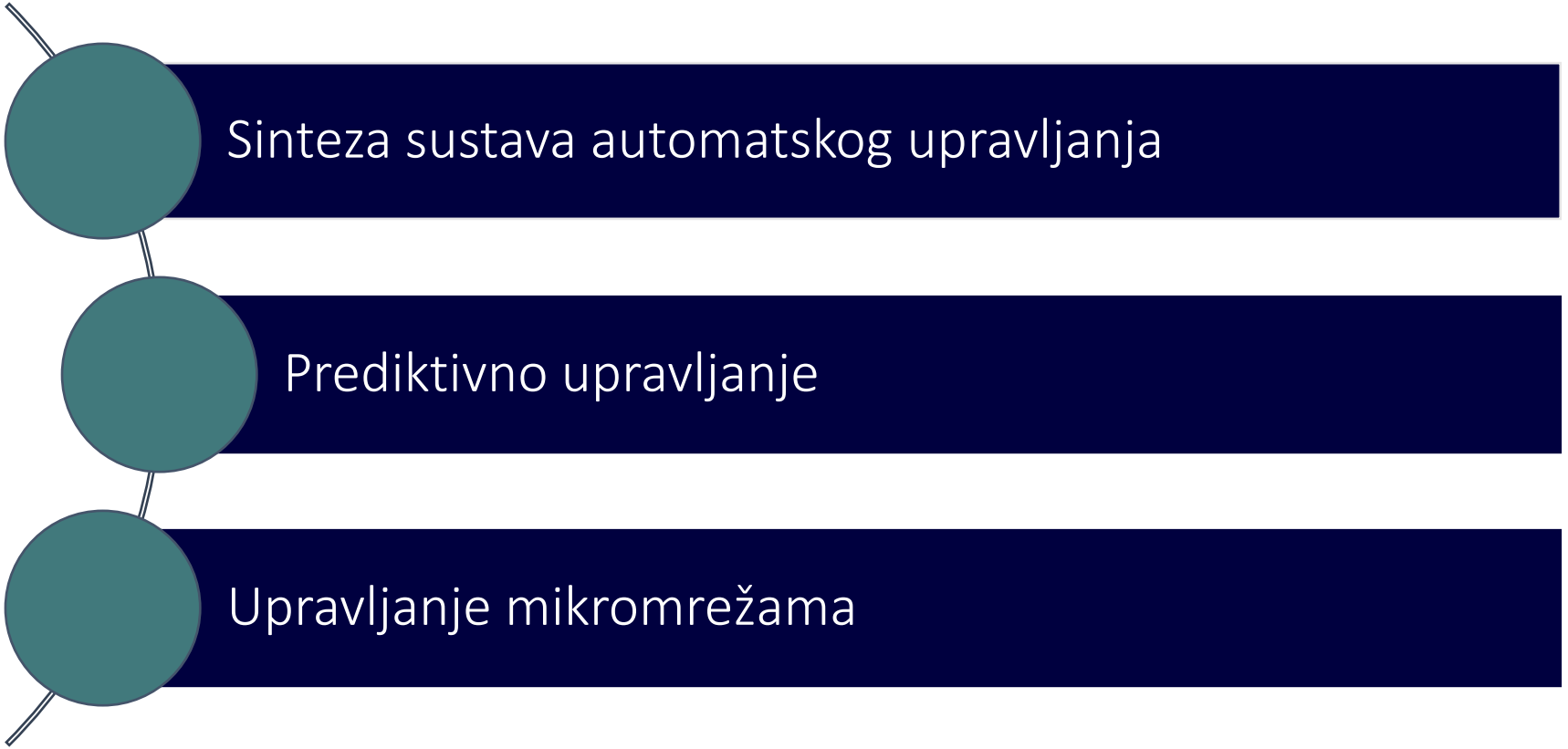
Kada će mi se investicija isplatiti?

Koliki elektrolizator, koliko panela, kakava baterija, koliki pretvarač...?

Združeno optimiranje za energetska čvorišta



AiR kolegiji i energetska čvorišta



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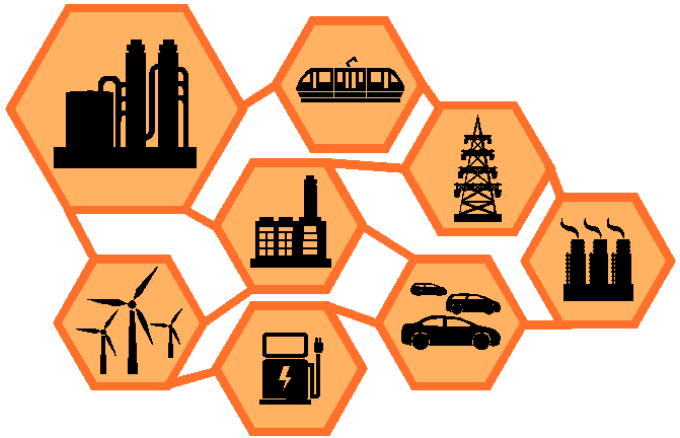
Systems of Systems – optimiranje rada složenih sustava

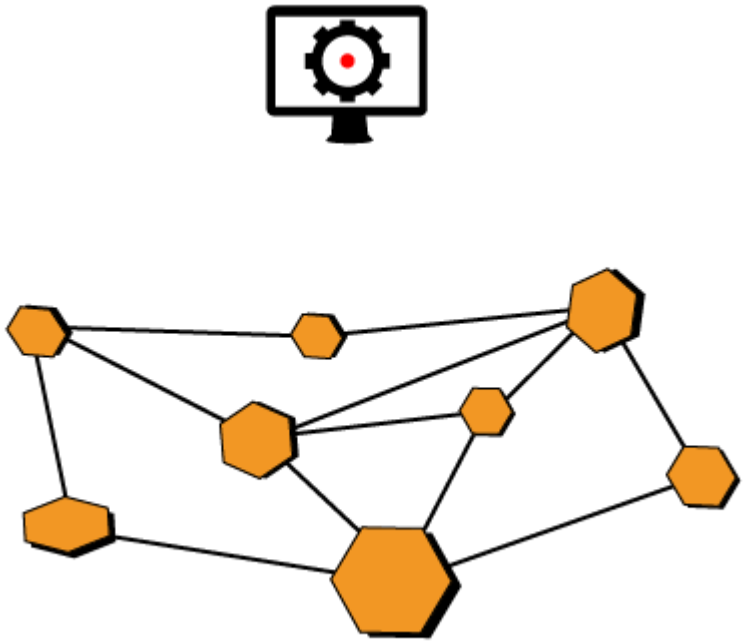
izv. prof. dr. sc. Branimir Novoselnik

Systems of Systems (SoS)

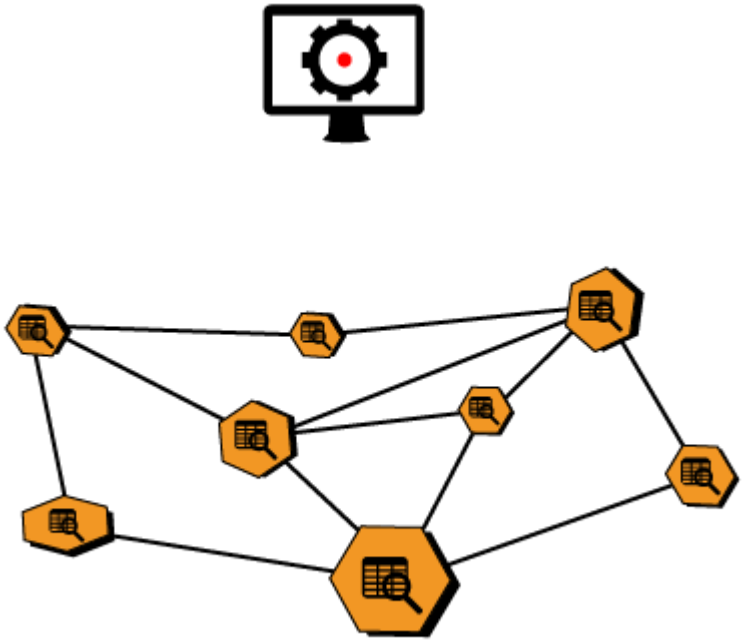
- Veliki socio-tehnički sustav sa složenim interakcijama
  - Veliki broj podsustava
  - Djelomična autonomija
  - Fizikalna sprega (npr. kroz tokove mase ili energije)
- Svi važni infrastrukturni sustavi
  - Elektroenergetski sustav
  - Industrijski kompleksi
  - Transportni sustavi
- Kompleksno dinamičko ponašanje
  - Nužno upravljanje kako bi se osiguralo optimalno ponašanje sustava



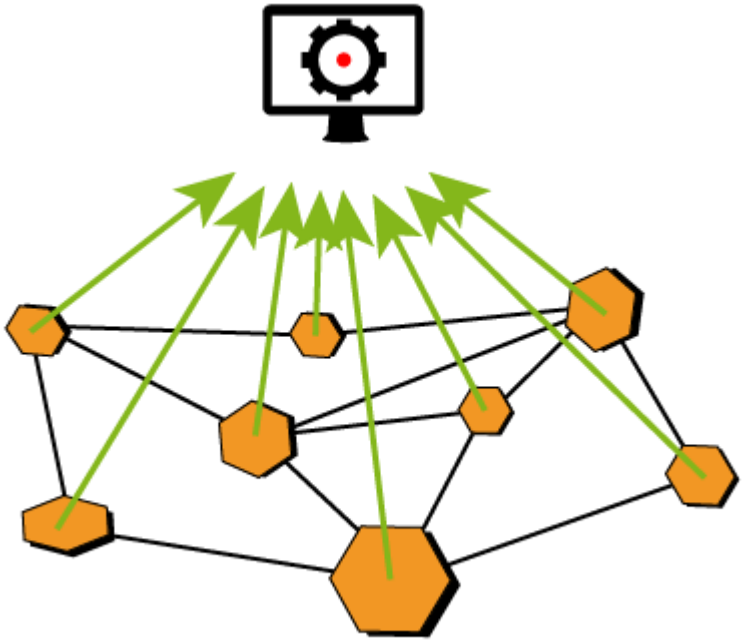
Globalna koordinacija



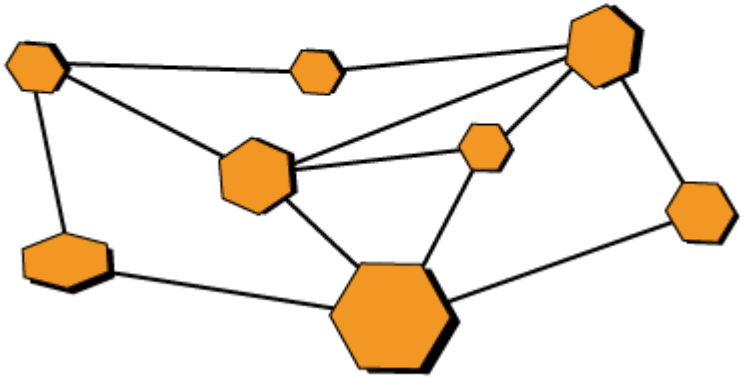
Globalna koordinacija



Globalna koordinacija



Globalna koordinacija



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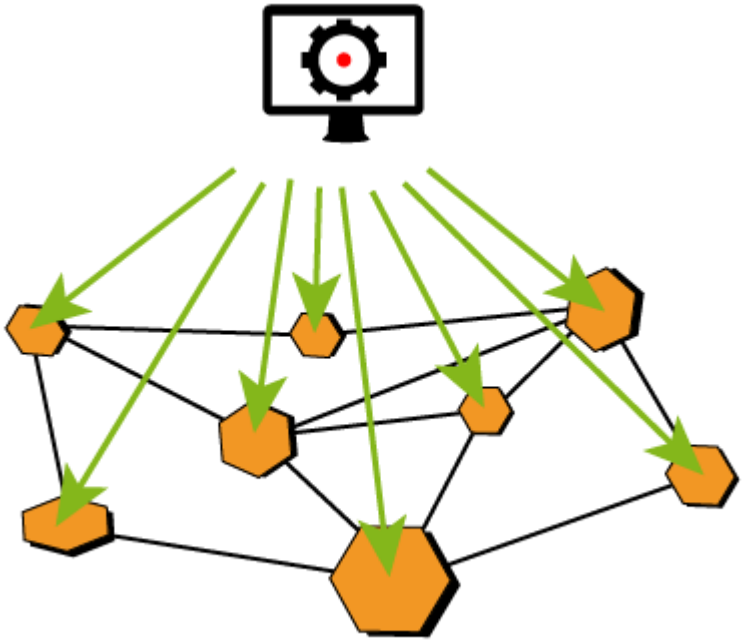

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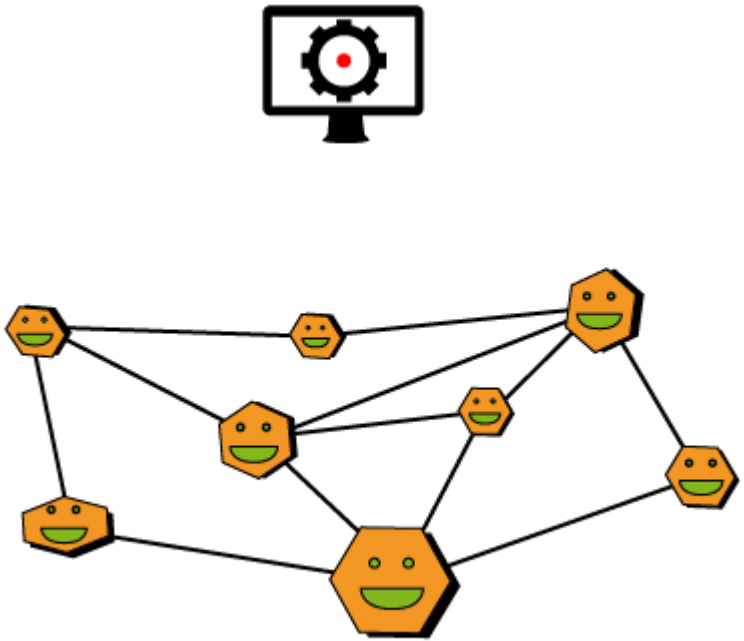
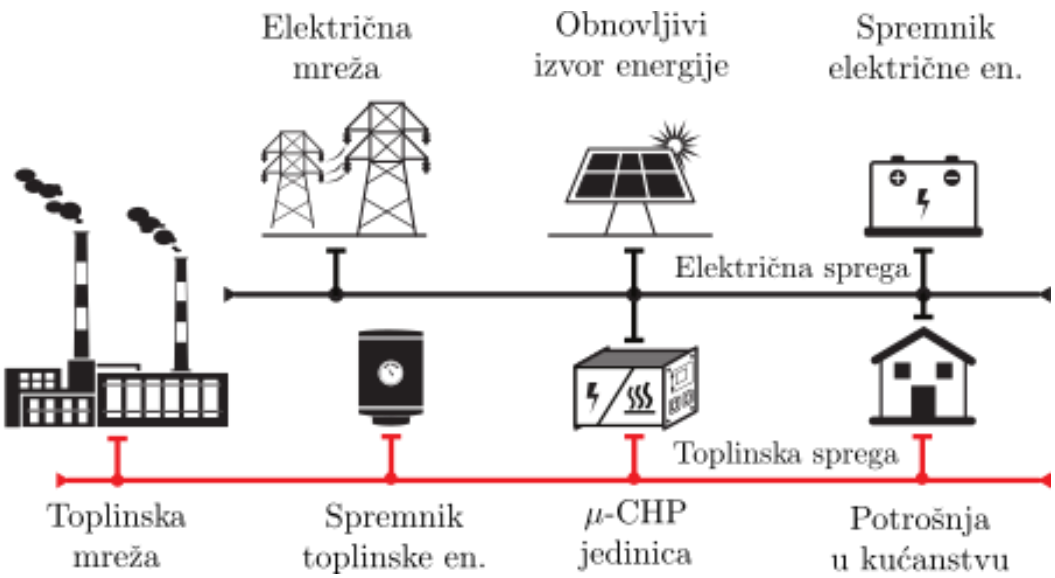
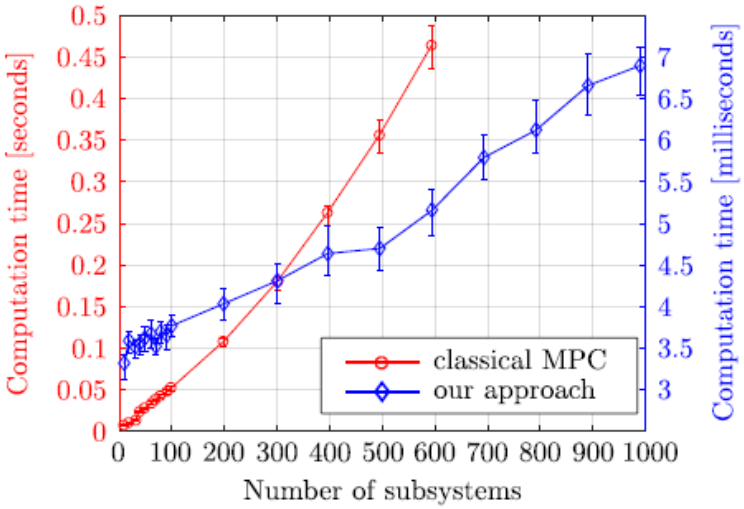


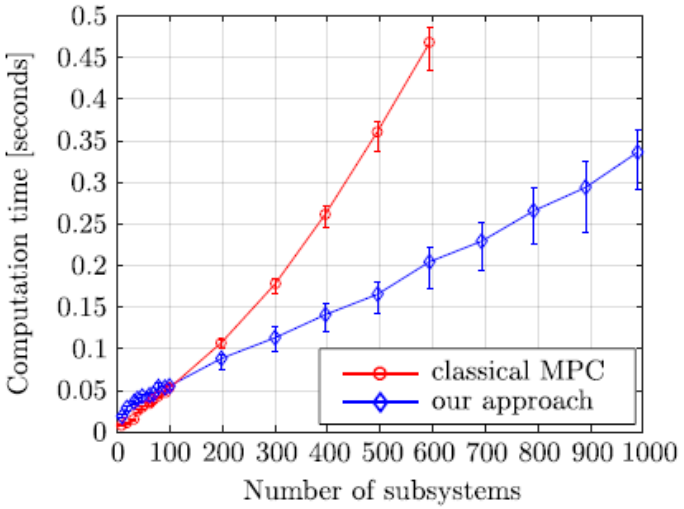
Primjer - mikromreža



Primjer - mikromreža

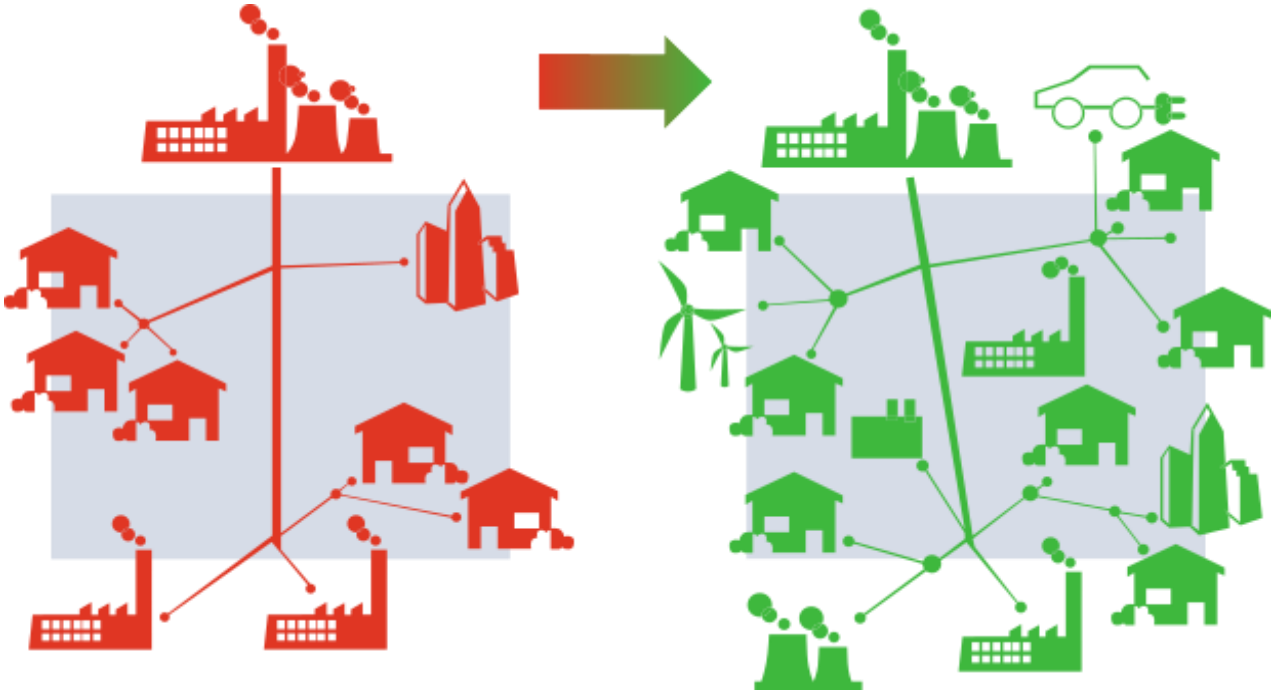


Jedna sprega

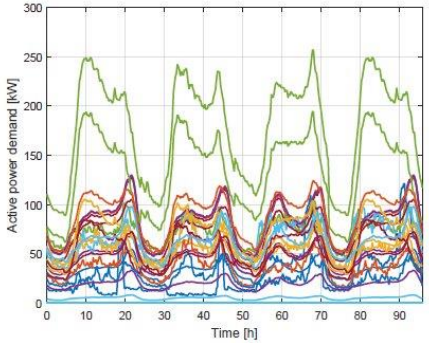


Dvije sprege

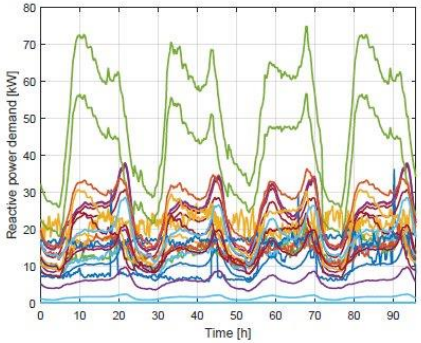
Primjer – distribucijski sustav



Primjer – distribucijski sustav

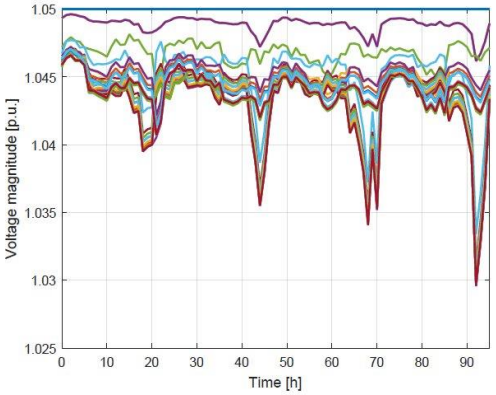


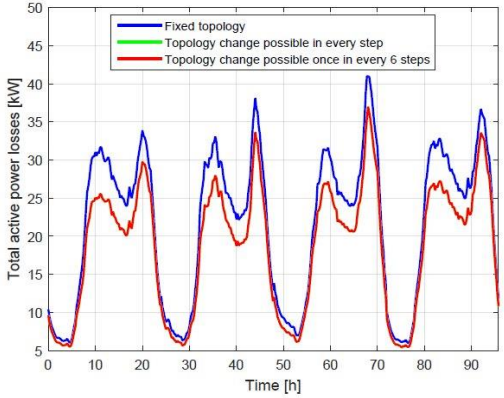
Active power demand



Reactive power demand

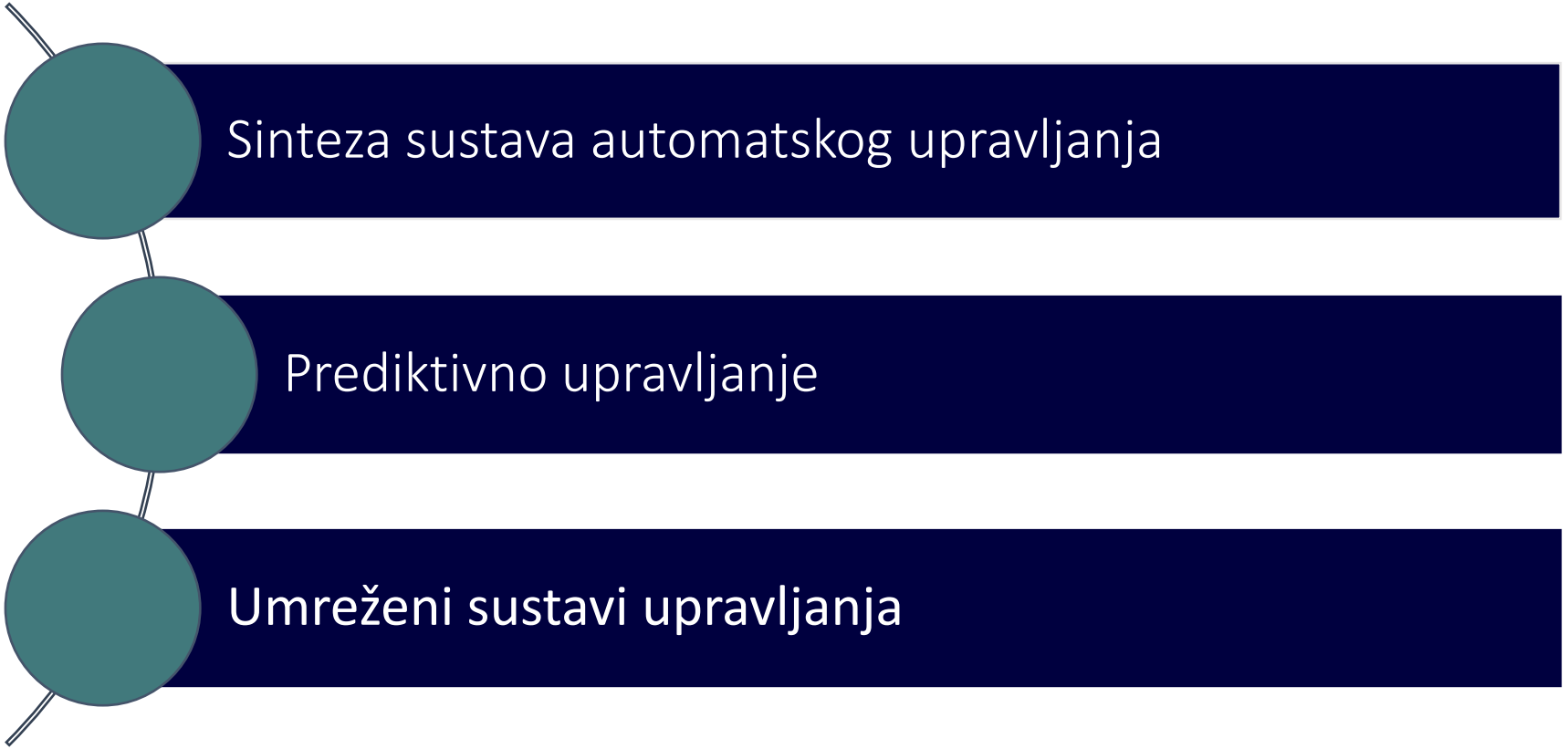
Naponi zadržani unutar ograničenja!





Gubitci smanjeni ~14%!

AiR kolegiji i Systems of Systems



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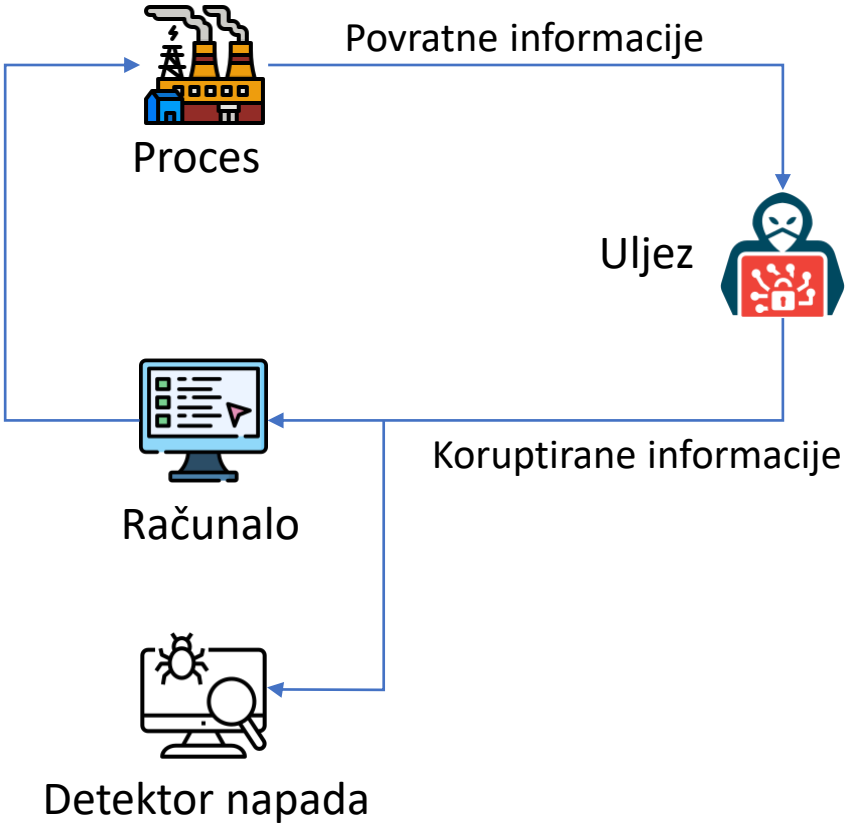
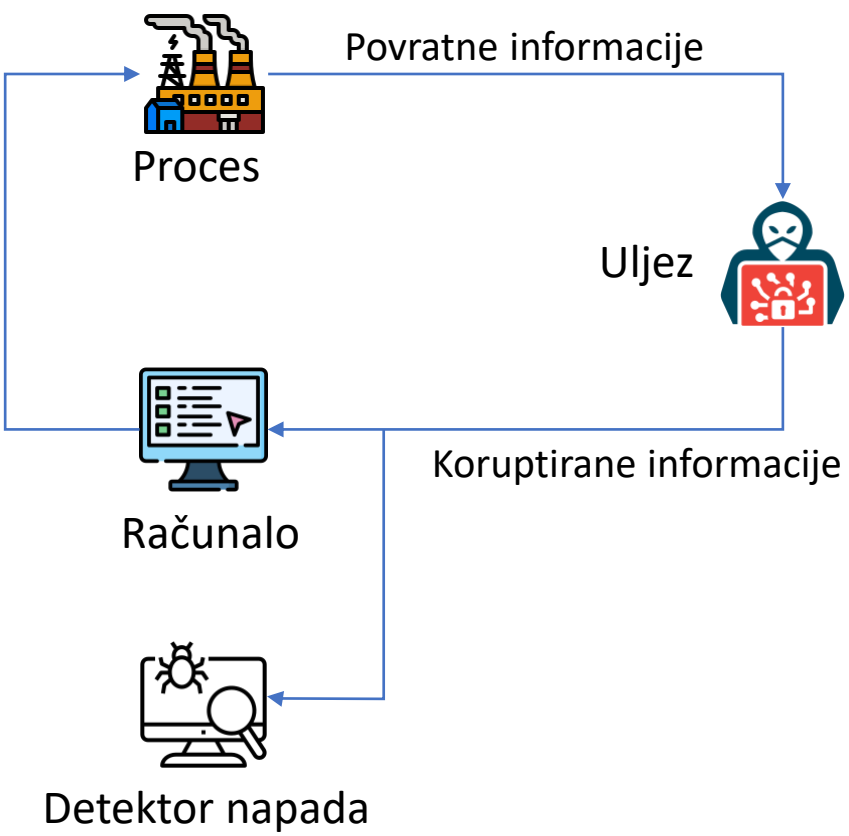
Kibernetička sigurnost upravljačkih sustava & BMS

Dorijan Leko, mag. ing.

Kibernetička sigurnost upravljačkih sustava

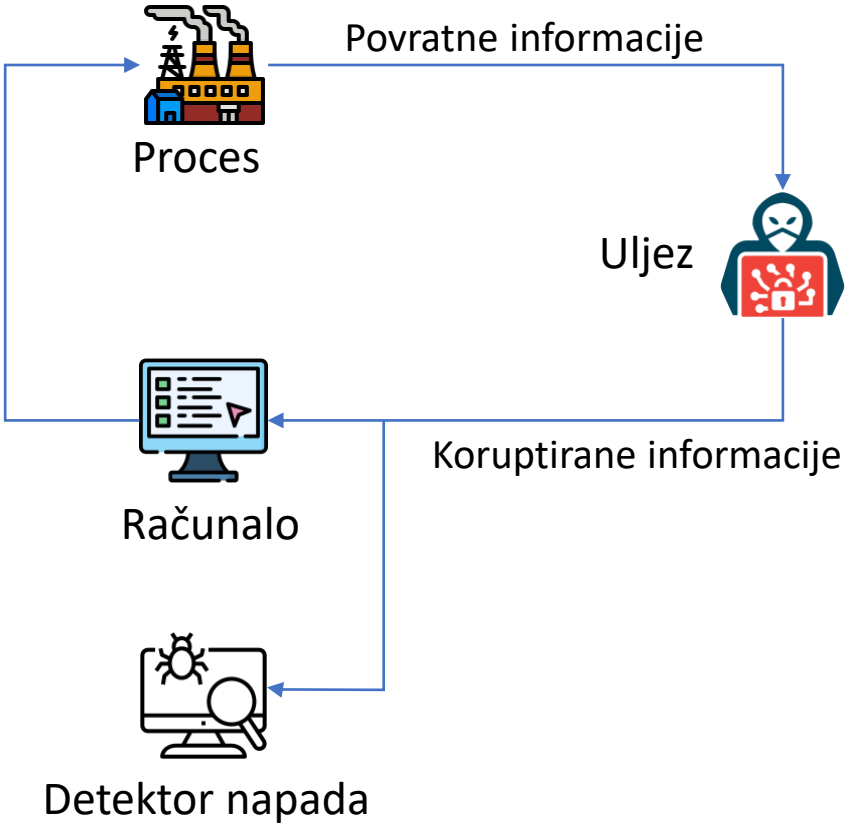


Kibernetička sigurnost upravljačkih sustava



Detektor napada:

Kibernetička sigurnost upravljačkih sustava



Detektor napada:

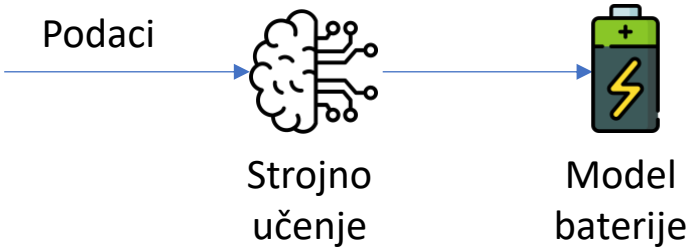
Model sustava → Računalna geometrija → Skup za detekciju napada

Uljez:

Informacija → Razviti strategiju napada i ostati neotkriven → Korupcija podataka

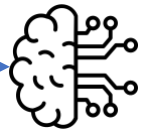
Sustav za gospodarenje baterijom

Izrada modela baterije:



Sustav za gospodarenje baterijom

Izrada modela baterije:

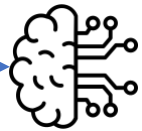
Podaci →  Strojno učenje →  Model baterije

Algoritam BMS-a:

Model baterije →  Računalna geometrija →  Skup dozvoljenih ponašanja baterije

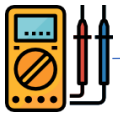
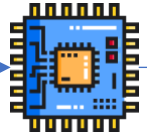
Sustav za gospodarenje baterijom

Izrada modela baterije:

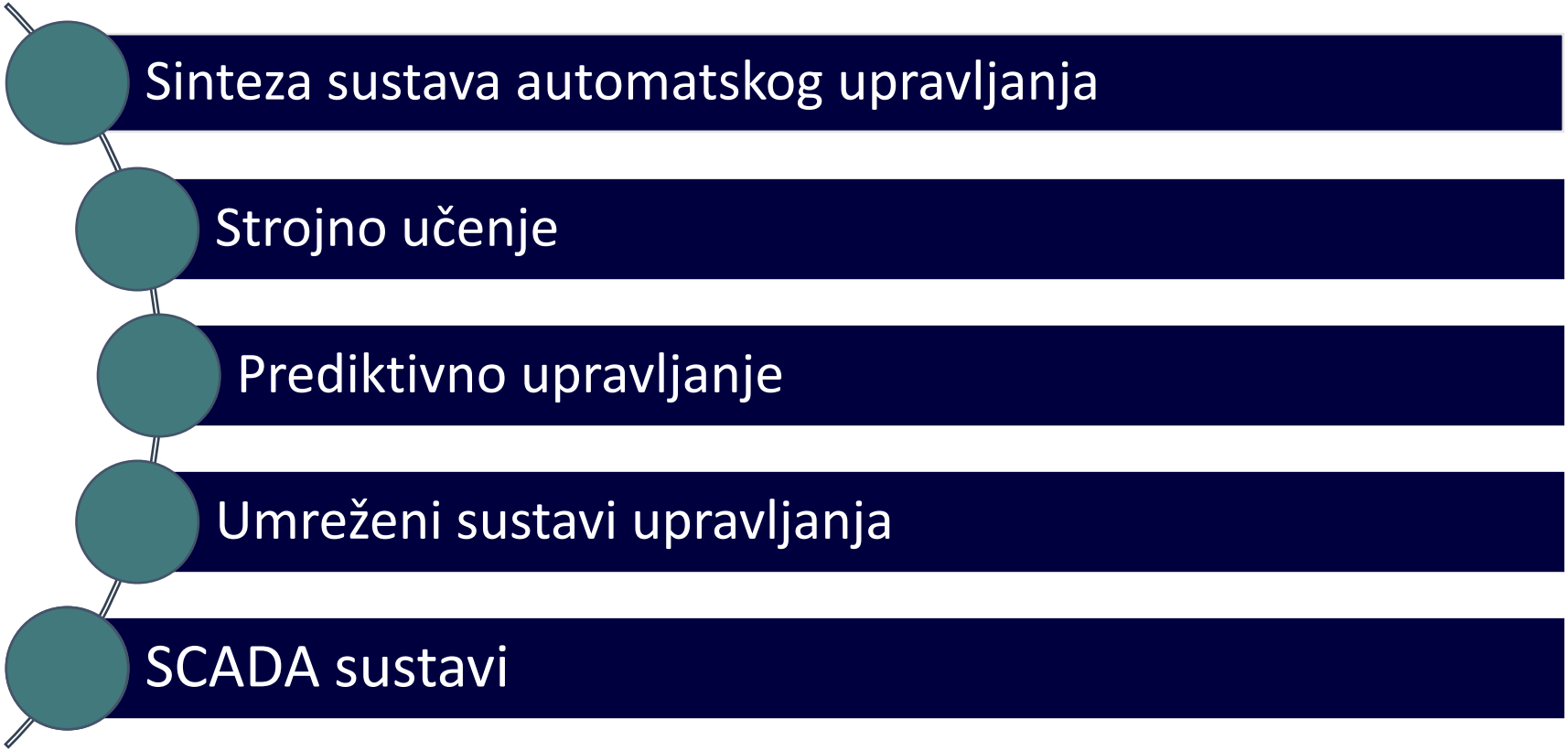
Podaci →  Strojno učenje →  Model baterije

Algoritam BMS-a:

Model baterije →  Računalna geometrija →  Skup dozvoljenih ponašanja baterije

 Mjerenja baterije u vozilu →  Ugradbeno računalo → Dozvoljene akcije el. automobila → 

AiR kolegiji

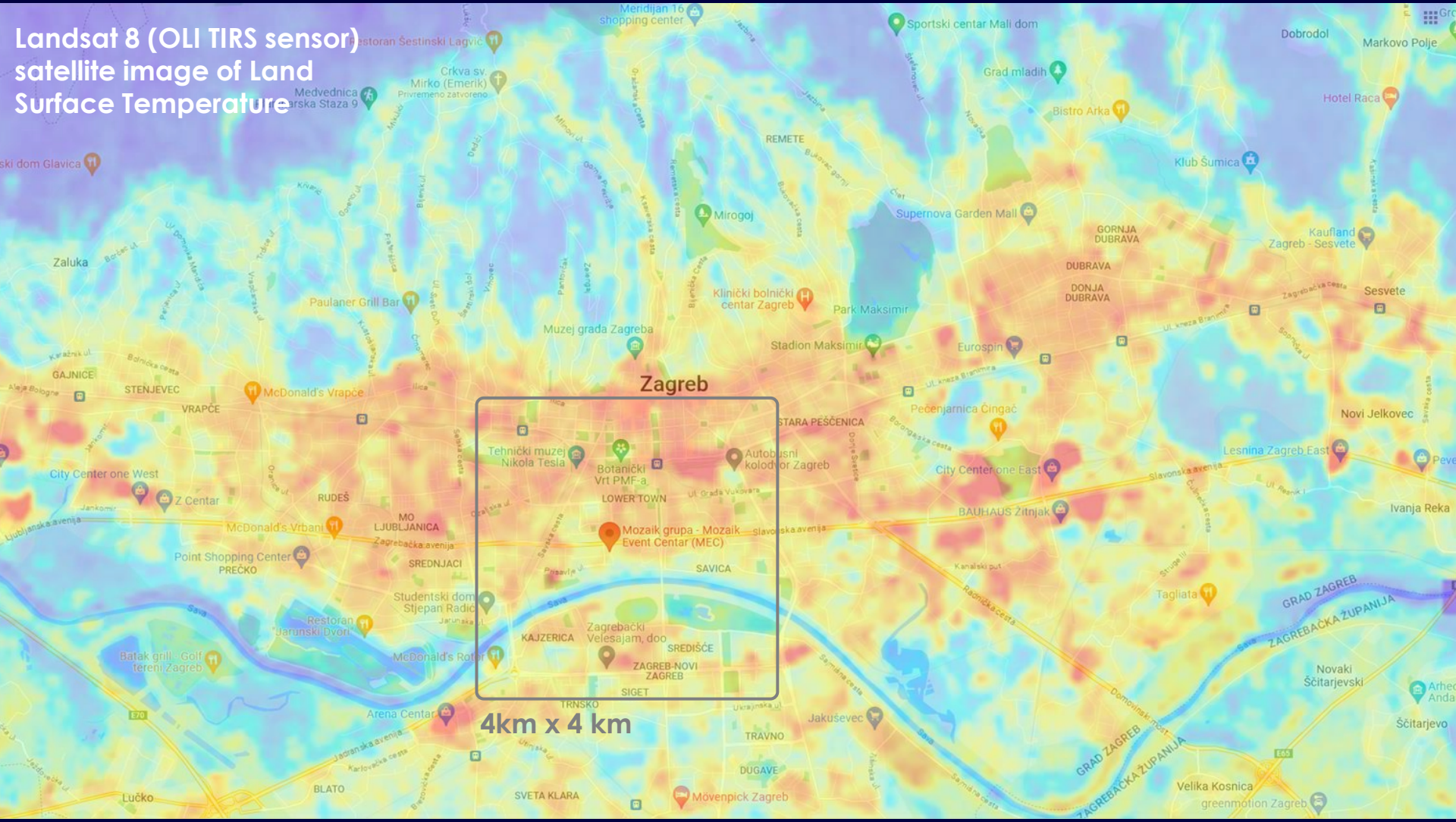


SVEUČILIŠTE U ZAGREBU
Fakultet elektrotehnike i računarstva

LARES
Laboratorij za sustave obnovljivih izvora energije

Meteorologija predvođena umjetnom inteligencijom

dr. sc. Hrvoje Novak


Landsat 8 (OLI TIRS sensor) satellite image of Land Surface Temperature
Zagreb
4km x 4 km
Meridijan 16 shopping center
Sportski centar Mali dom
Dobrodol
Markovo Polje
Grad mladih
Hotel Raca
Bistro Arka
Klub Šumica
REMETE
Mirogoj
Supernova Garden Mall
GORNJA DUBRAVA
DUBRAVA
DONJA DUBRAVA
Kaufland Zagreb - Sesvete
Sesvete
Zaluka
Paulaner Grill Bar
Klinički bolnički centar Zagreb
Park Maksimir
Muzej grada Zagreba
Stadion Maksimir
Eurospin
GAJNICE
STENJEVEC
VRAPČE
McDonald's Vrapče
STARA PEŠČENICA
Pečenjarnica Čingač
Novi Jelkovec
Tehnički muzej Nikola Tesla
Botanički Vrt PMF-a
Autobusni kolodvor Zagreb
City Center one West
Z Centar
RUDEŠ
LOWER TOWN
City Center one East
Lesnina Zagreb East
MO LJUBLJANICA
McDonald's Vrbani
Mozaik grupa - Mozaik Event Centar (MEC)
BAUHAUS Žitnjak
Ivanja Reka
Point Shopping Center PREČKO
SREDNJACI
SAVICA
Tagliata
GRAD ZAGREB
ZAGREBAČKA ŽUPANIJA
Studentski dom Stjepan Radić
Restoran "Jarunski Dvori"
KAJZERICA
Zagrebački Velesajam, doo
SREDIŠĆE
ZAGREB-NOVI ZAGREB
Batak grill - Golf teren Zagreb
McDonald's Rotor
SIGET
TRNSKO
Arena Centar
Jakuševec
Novaki Ščitarjevski
TRAVNO
DUGAVE
Ščitarjevo
Velika Kosnica
greenmotion Zagreb
Lučko
BLATO
SVETA KLARA
Mövenpick Zagreb

Napredne meteorološke prognoze

Zašto?

Točnije prognoze, bolje informiranje korisnika i podrška u odlučivanju za sektore poput poljoprivrede, energetike, …

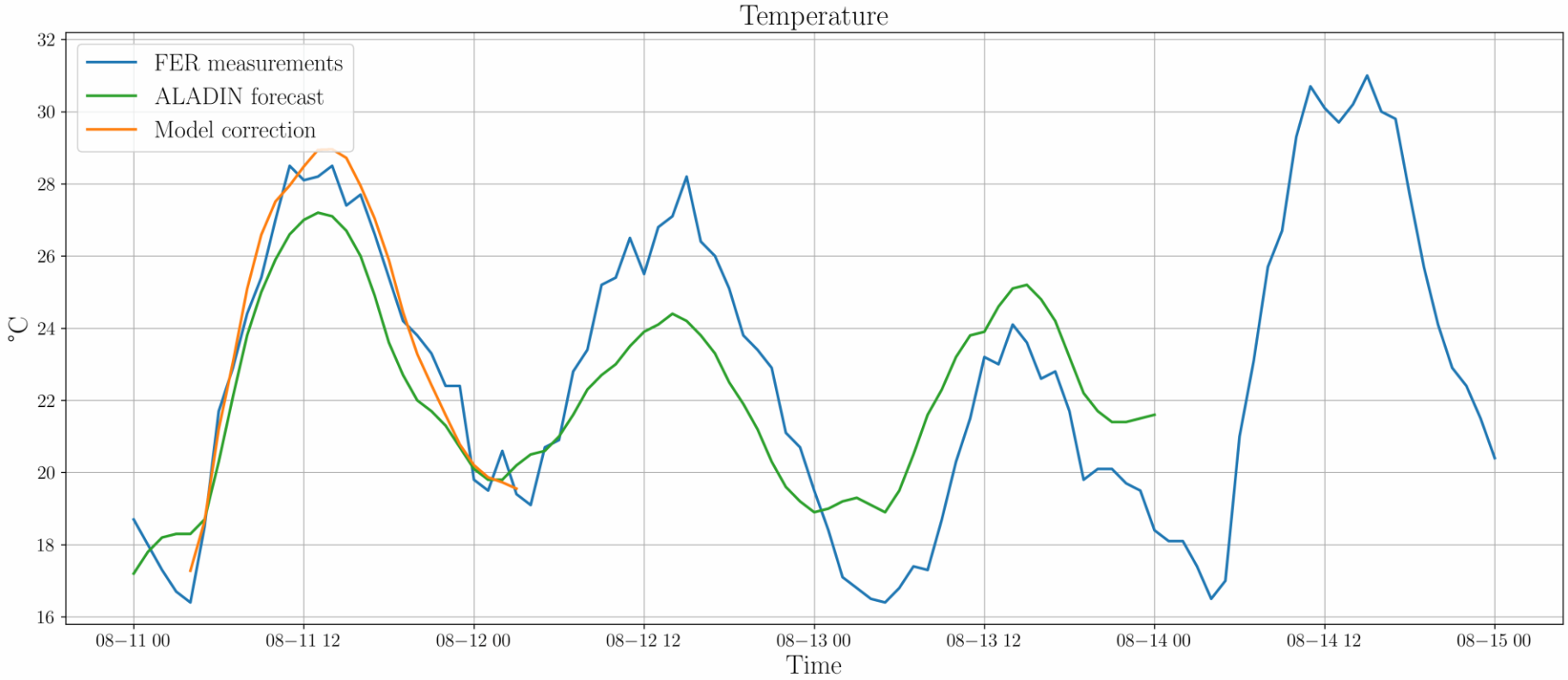
Što?

Lokalizacija, korekcija, transformacija i prilagodba vremenskih prognoza

Kako?

Korištenjem različitih izvora podataka (lokalne postaje, modeli, sateliti, radar) i AI algoritama

Aladin-HR – rezultati



Geographical location: All | Meteorological variable: Air temperature at 2m | Forecast start time: 12-05-2025 15:00:00 | NWP model: ECMWF IFS 0.25° | Current time | now-14d to now+7d UTC | Refresh 1h

OSAKA EXPO 2025

University of Zagreb Faculty of Electrical Engineering and Computing

UNIVERSITY OF ZAGREB
Faculty of Electrical Engineering and Computing

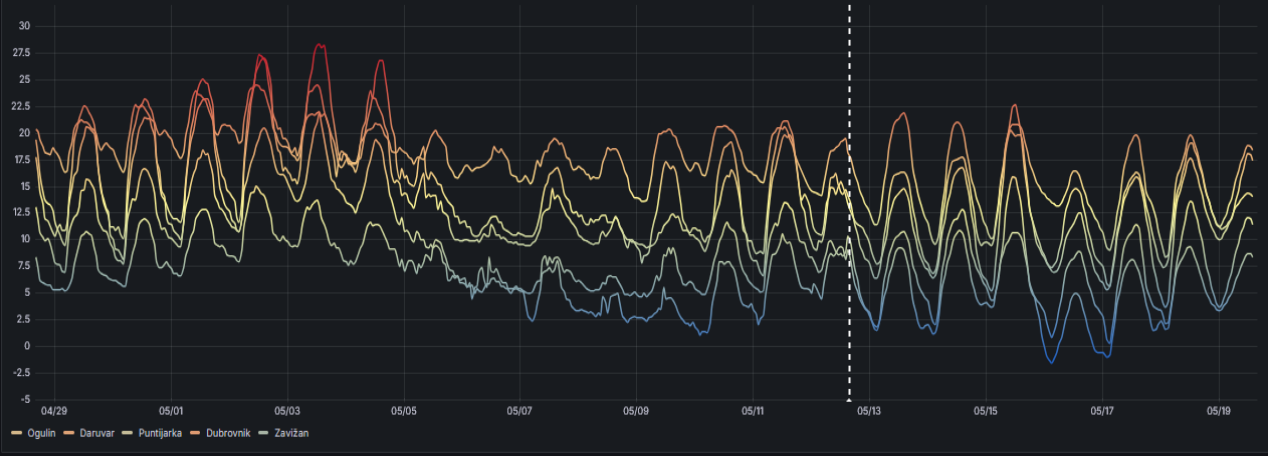
Laboratory for Renewable Energy Systems

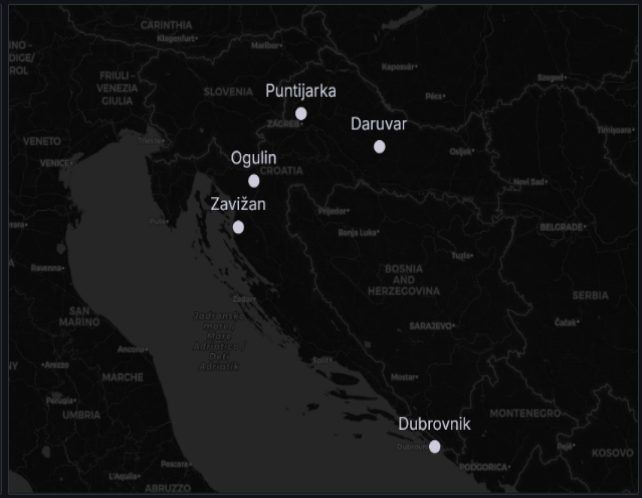
DHMZ: Meteorological Research and Development Sector

Current weather status

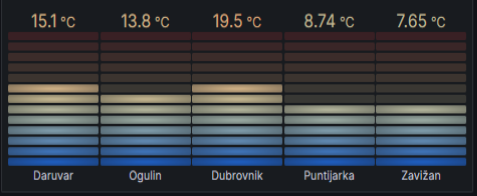
Daruvar	Mainly clear, partly cloudy, and overcast
Ogulin	Mainly clear, partly cloudy, and overcast
Dubrovnik	Mainly clear, partly cloudy, and overcast
Puntijarka	Mainly clear, partly cloudy, and overcast
Zavižan	Mainly clear, partly cloudy, and overcast

Air temperature at 2m - historical measurements

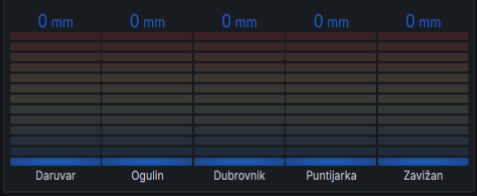




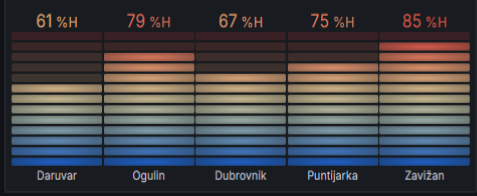
Air temperature at 2m



Total precipitation



Relative humidity at 2m



Global irradiance

Current meteorological conditions

Location	Air temperature 2m	Relative humidity 2m	Dew point 2m	Precipitation	Weather code	Global irradiance	Diffuse irradiance	Direct irradiance	Wind speed 10m	Wind direction 10m	Surface pressure
Daruvar	15.1	61	7.60	0	2	421	199	372	15.2	76.3	996
Ogulin	13.8	79	10.2	0	3	103	97	8.90	8.50	36.4	975
Dubrovnik	19.5	67	13.2	0	1	510	149	605	7.42	256	1003
Puntijarka	8.74	75	4.55	0	3	344	213	216	15.3	80.5	901
Zavižan	7.65	85	5.29	0	2	466	164	486	16.1	74.4	837


OSAKA, KANSAI, JAPAN
EXPO
2025

人工知能主導の気象学：天気と持続可能性の未来を形作る
AI-Driven Meteorology: Shaping the Future of Weather and Sustainability

IEEE R8 Climate Challenges – AI in Enhanced Weather Forecasting

- Međunarodno natjecanje
- AI modeli i fuzija podataka
- 16 timova
- 15-60% poboljšanje
- IEEE IHTC 2024

IEEE Region 8 Climate Challenges
AI in Enhanced Weather Forecasting

IEEE Region 8 Climate Challenges | IEEE Region 8 | IEEE Foundation | IEEE Humanitarian Technologies

IEEE Region 8
Climate Challenges
AI in Enhanced Weather Forecasting

Submit your solutions by 1-NOV-2024

IEEE DataPort™

10106 Views

IEEE Region 8
Humanitarian Technology Activities Committee

„AI WEATHER FORECASTING CHALLENGE”

GLOBALNO NATJECANJE KOJE SE ODRŽAVA NA KAGGLEU S CILJEM UNAPRJEĐENJA PREDIKTIVNIH VREMENSKIH MODELA POMOĆU AI/ML:

- Svjetska ML pozornica
- 23+ M korisnika, ~1700 timova po natjecanju
- 5 regija (1 u RH – DHMZ)
- $50k nagradni fond

U organizaciji s vodećim institucijama u području:

UNITED NATIONS

IEEE

WORLD METEOROLOGICAL ORGANIZATION

SVEUČILIŠTE U ZAGREBU
Fakultet elektrotehnike i računarstva

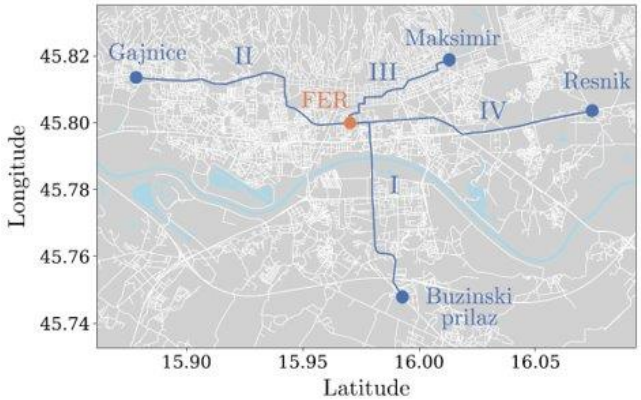
LARES
Laboratorij za sustave obnovljivih izvora energije

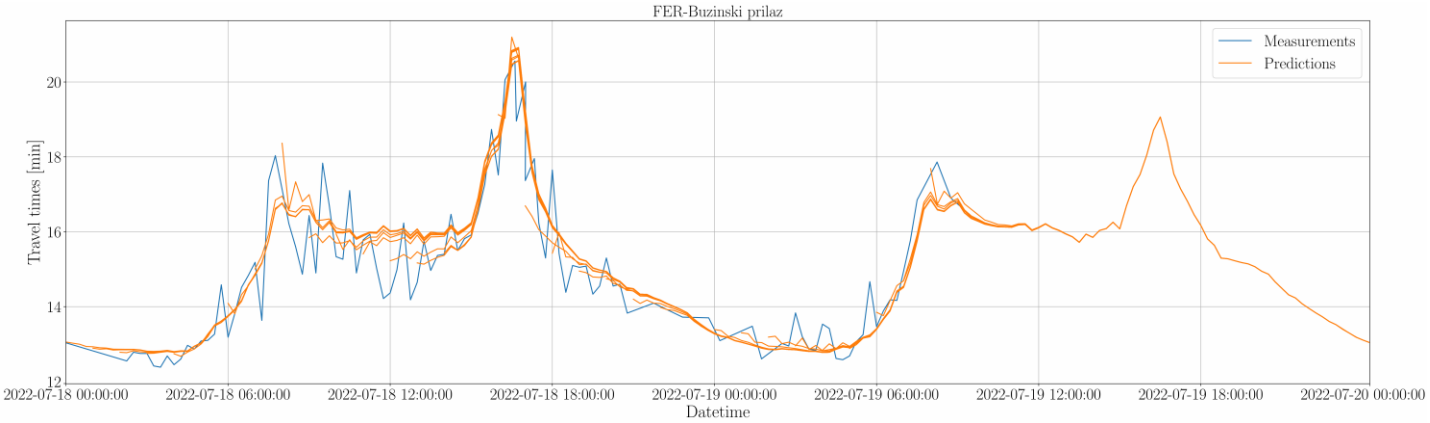
Urbana rasvjeta i gradski promet

izv. prof. dr. sc. Vinko Lešić

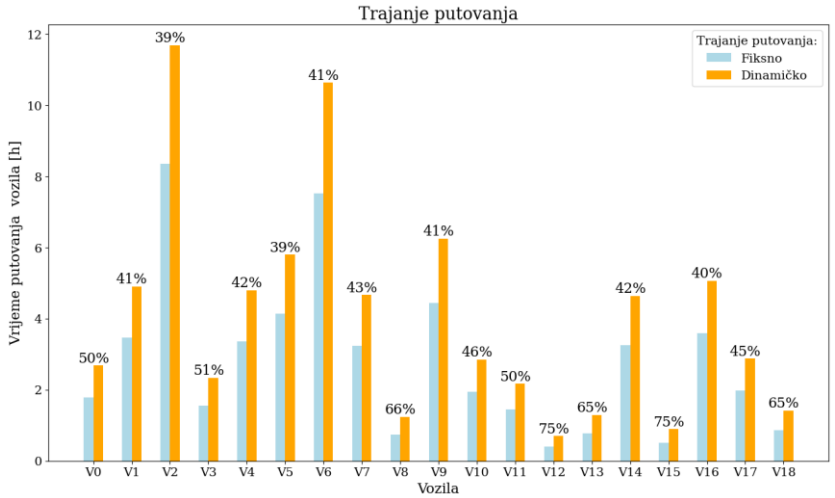
Predikcija prometa

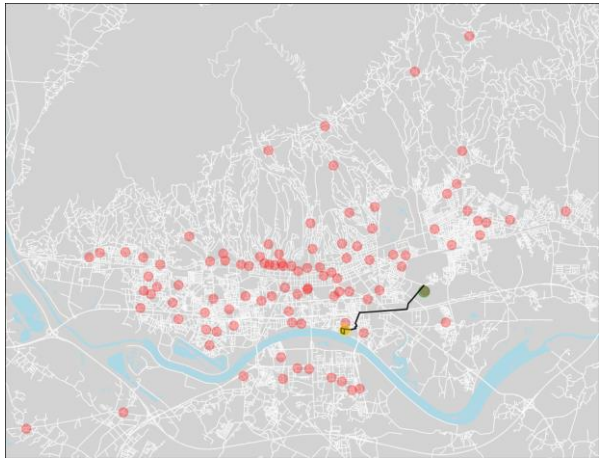
- Podaci navigacijskih servisa
- 15 min do 24 h unaprijed
- 95 – 97% preciznost za Zagreb
- Strojno učenje – predviđanje vremenskih serija



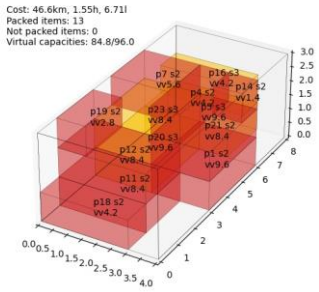


Urbana logistika



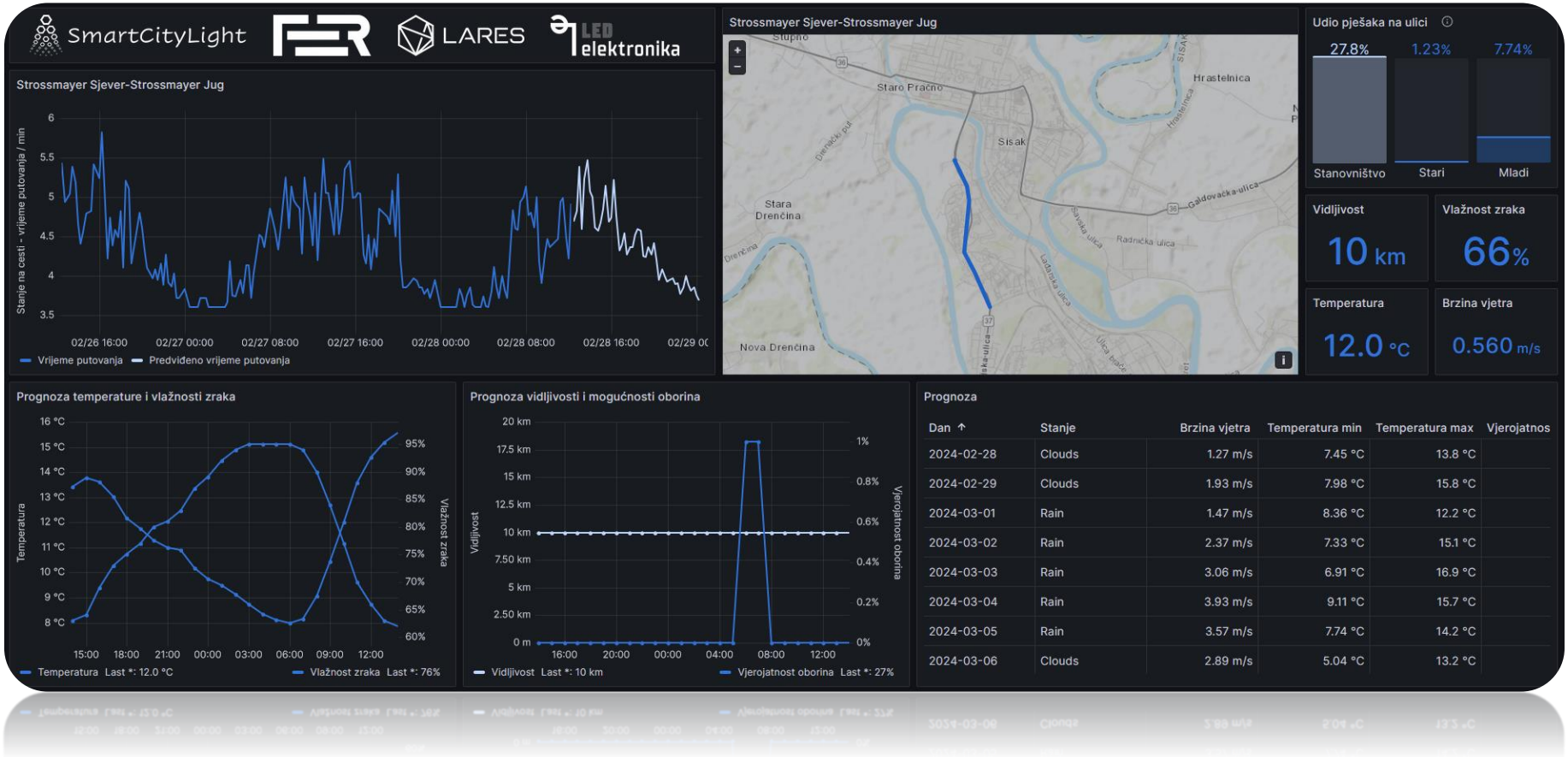


- Predikcija potražnje
- Prediktivna optimizacija ruta (VRP)
- Prediktivna optimizacija utovara (BP)
- Metaheuristički algoritmi

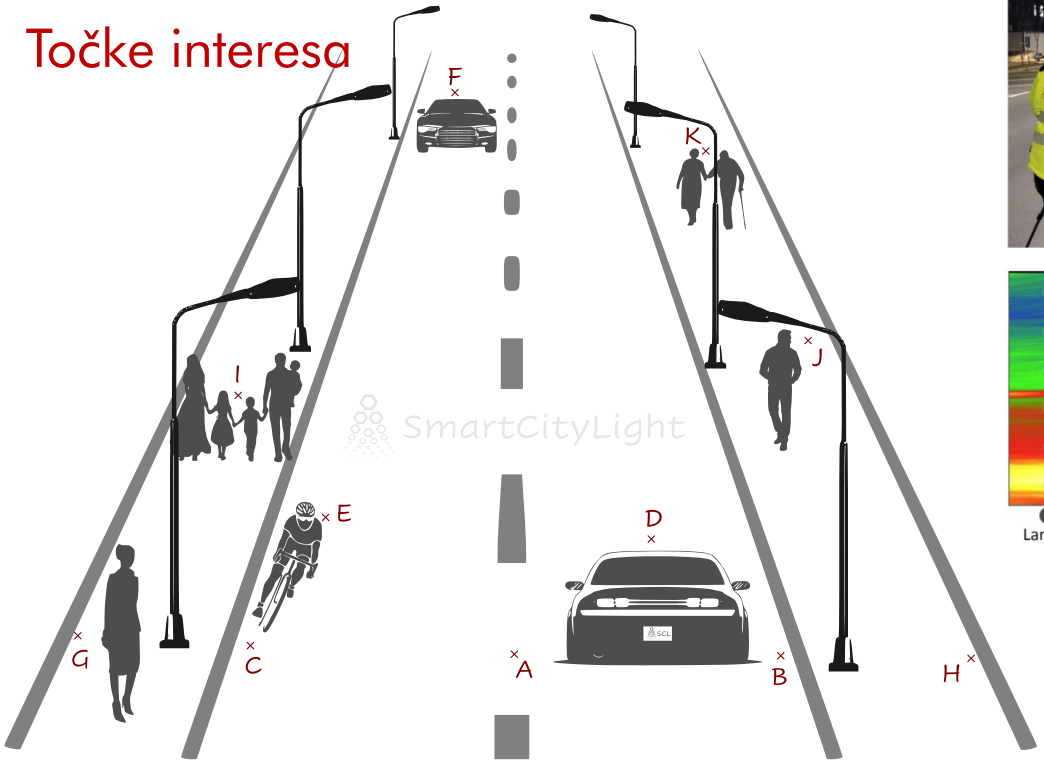


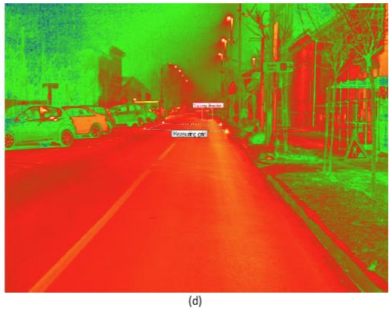
- Koordinirani VRP and BP
- 5-20% poboljšanje učinkovitosti ruta

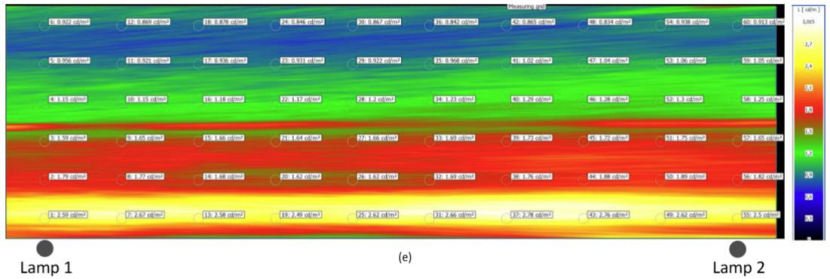
Sisak „living lab”



Smart City Light







Sisak pilot – J.J. Strossmayera

Patenti EP4369867, EP4369868

SVEUČILIŠTE U ZAGREBU
Fakultet elektrotehnike i računarstva

LARES
Laboratorij za sustave obnovljivih izvora energije

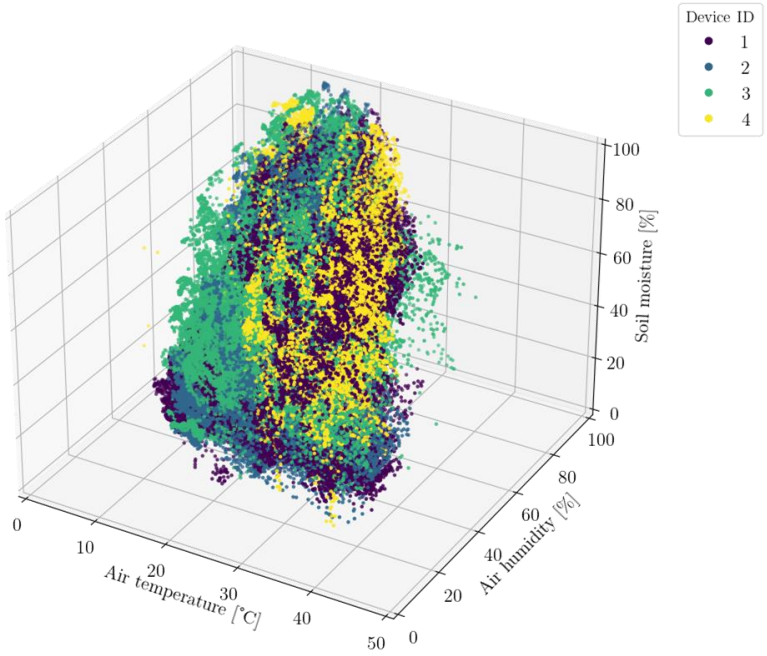
Napredna i precizna poljoprivreda

izv. prof. dr. sc. Vinko Lešić

Četiri komore. Pedeset senzora. I jedna robotska ruka. Tako na vrhu nebodera FER-a raste **pšenica sudnjeg dana**. Biljke isušuju, poplavljuju i testiraju na pet tisuća klimatskih scenarija. Cilj je jedan: spasiti usjeve budućnosti

Foto: Marko Miščević - Cropix

Prediktivna poljoprivreda

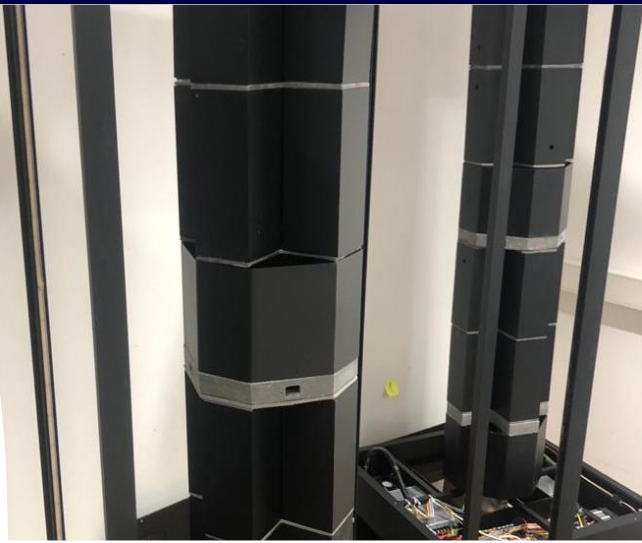


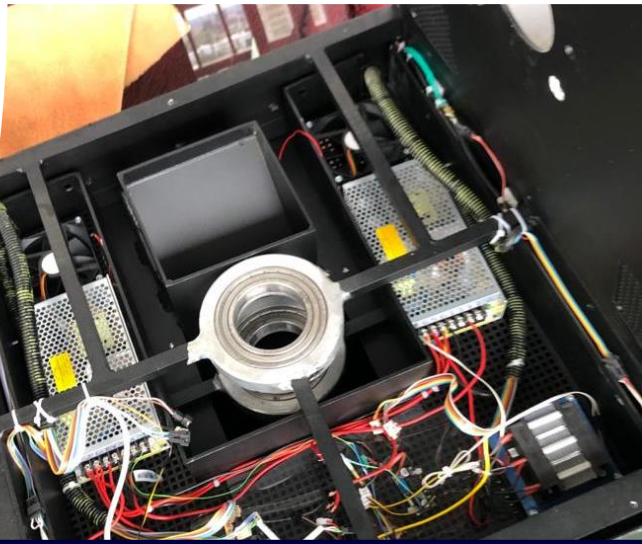
5000 klimatskih scenarija

6 mil. zapisa u bazu

Iza scene

- Istraživanje tržišta i koncept
- Dizajn komora
- Elektronika i IoT senzori
- Wi-Fi komunikacija
- MS Azure i IoT
- SQL i arhiviranje
- Regulacija klime
- Napredni algoritmi





LARES

URBAN OASIS

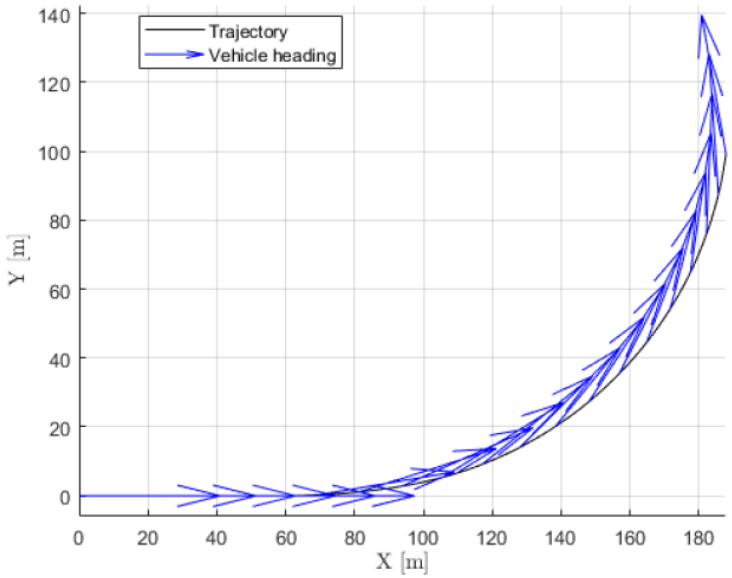
studentski spin-off

SVEUČILIŠTE U ZAGREBU
Fakultet elektrotehnike i računarstva

LARES
Laboratorij za sustave obnovljivih izvora energije

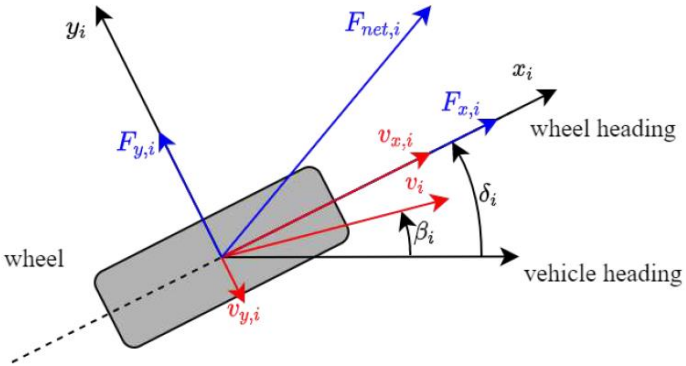
AiR LARES studenti

drift at v = 30 m/s



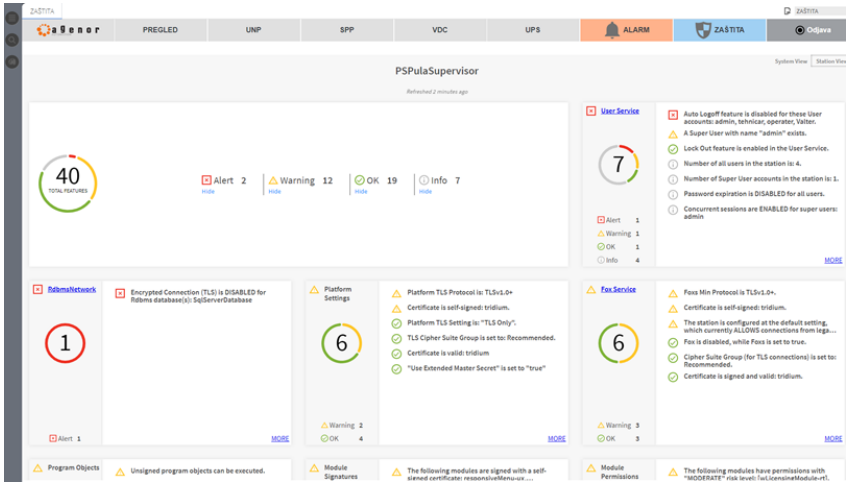
Nikola Benazić, „Model predictive control of the vehicle lateral force for driver assistance”
diplomski rad br. 2236

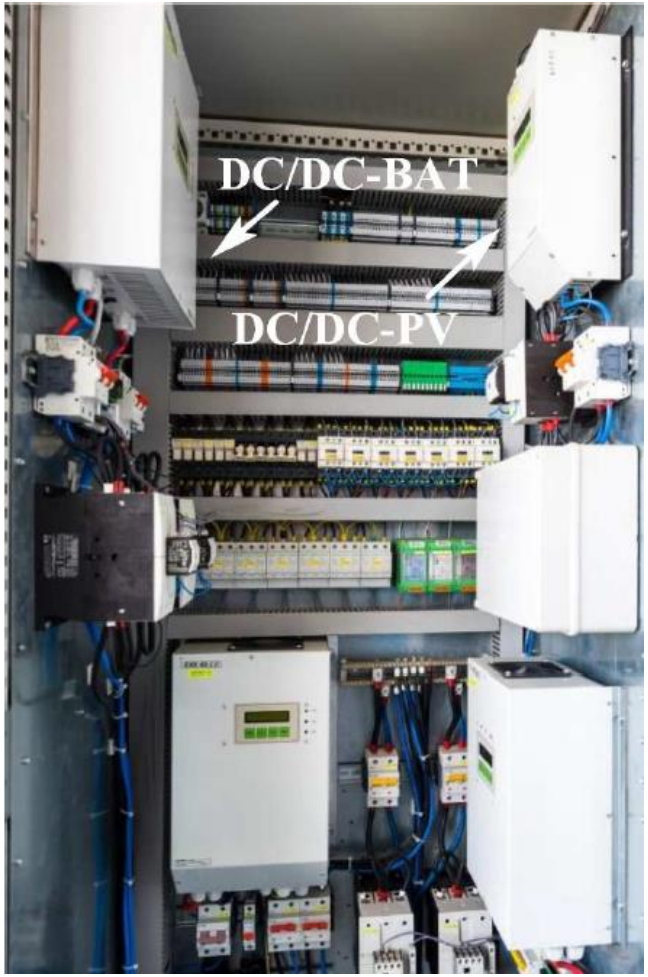
RIMAC TECHNOLOGY



Nikolina Jurković, „Cloud-based monitoring of a central gas distribution system”
diplomski rad br. 2052

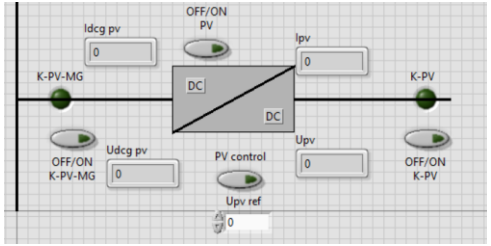
LED elektronika

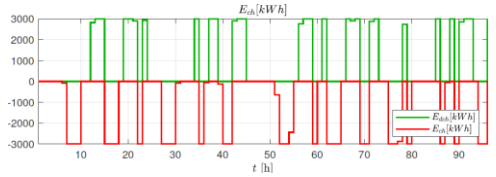


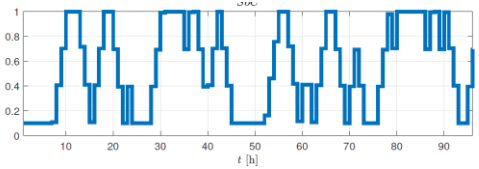


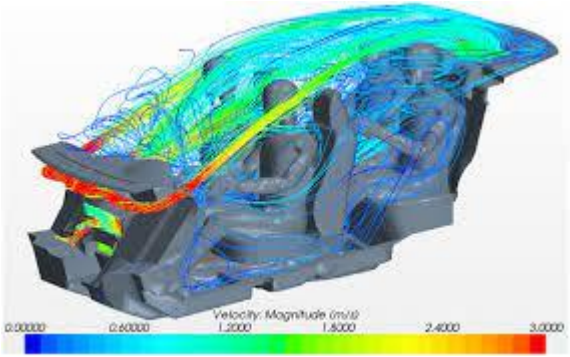
Benjamin Schwirtlich, „Predictive microgrid control with renewable energy systems”
diplomski rad br. 2387

AVL



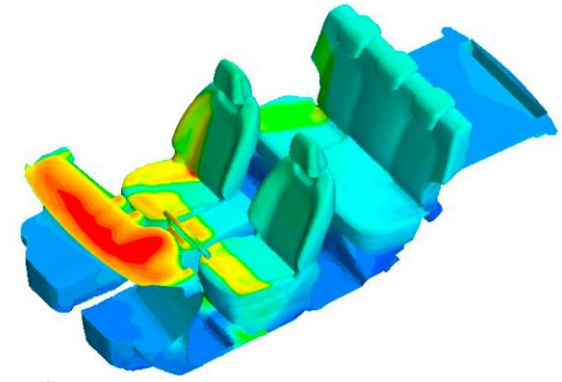


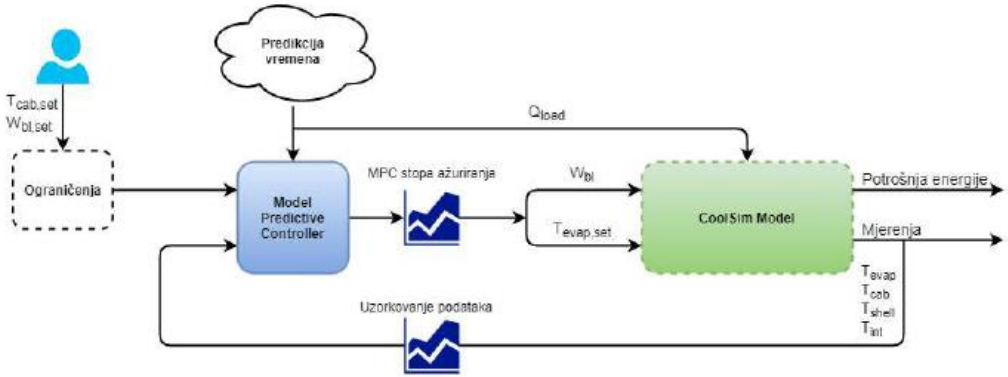




Ena Mikulić, „Prediktivno upravljanje sustavom klimatizacije kabine električnog automobila”
diplomski rad br. 2238

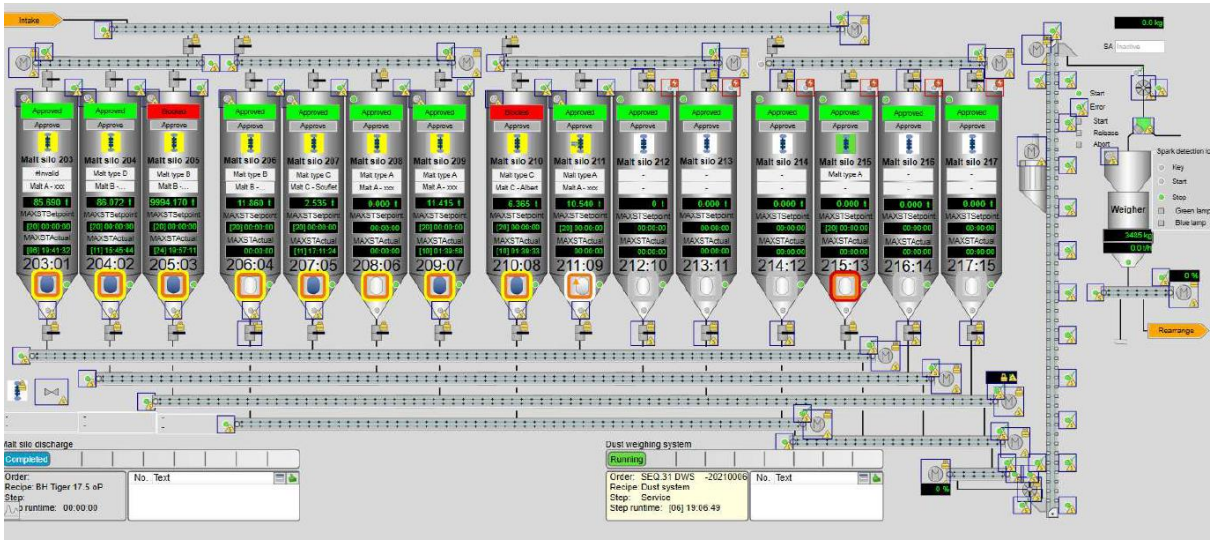
BUGATTI RIMAC

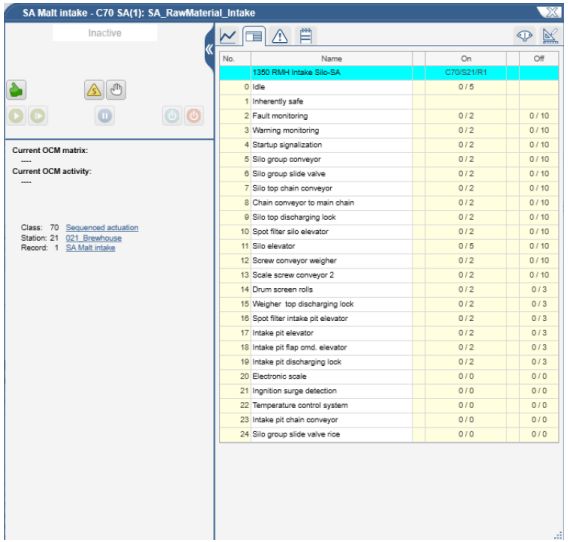




David Pokrajčić, „Daljinsko upravljanje dijelom procesa proizvodnje piva”
diplomski rad br. 2239

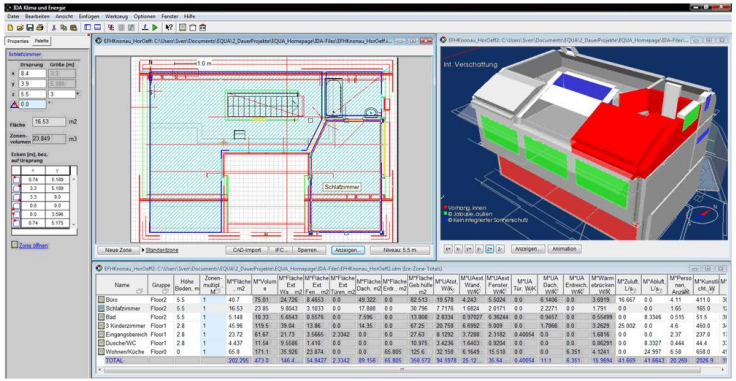
MONTELEKTRO

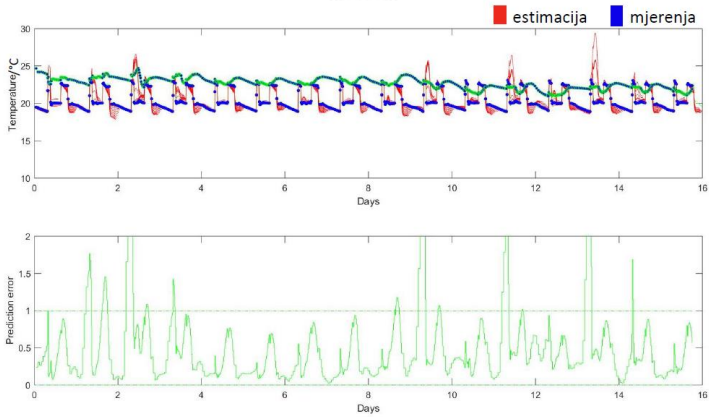




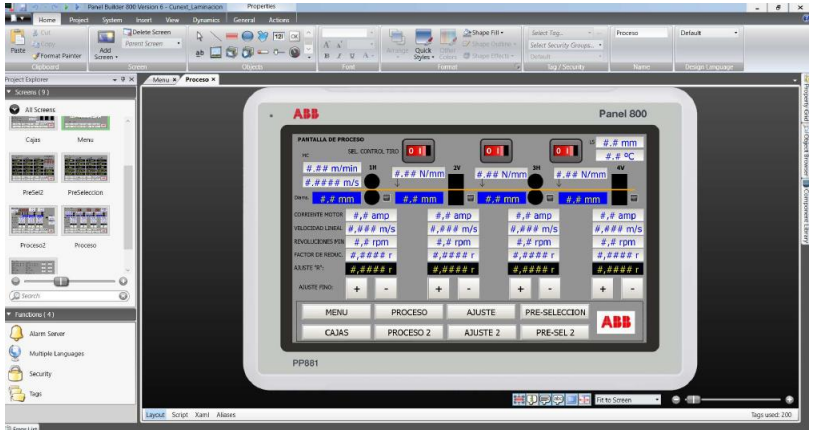
Ivana Bašljan, „Analiza mogućih ušteda optimalnim upravljanjem potrošnjom rezidencijalnih jedinica u naprednim gradovima”
diplomski rad br. 1881

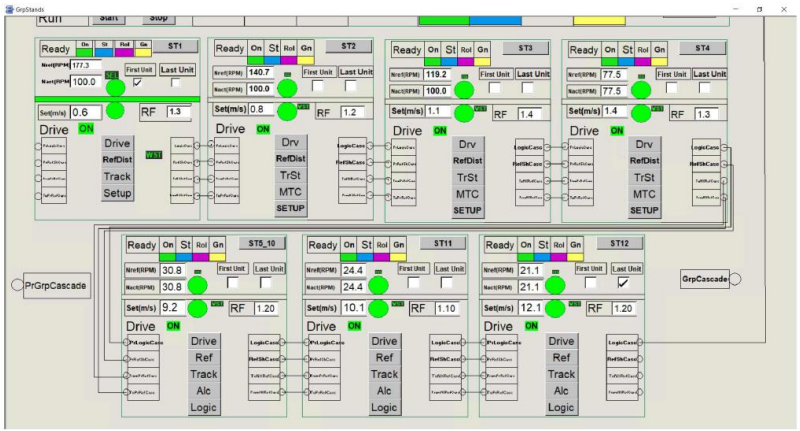
DOK-ING

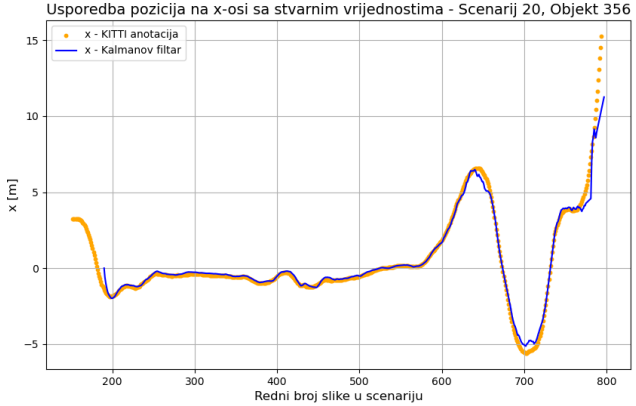




Matija Mrvčić, „Upravljanje žičnom prugom u postupku vrućeg valjanja”
diplomski rad br. 105

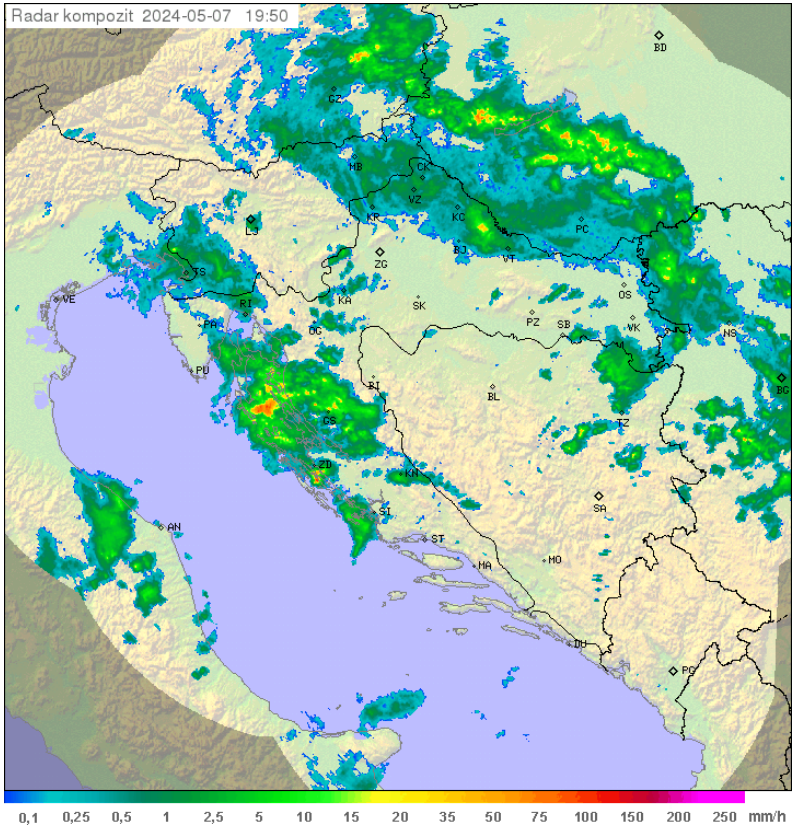




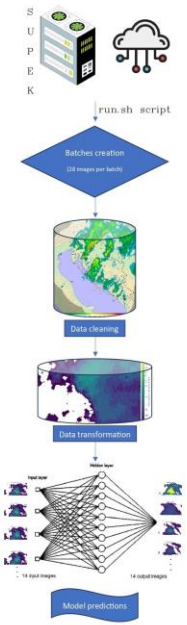


Hrvoje Komušar, „Lokalizacija i praćenje objekata na nizu sekvencijalnih slika korištenjem dubokih neuronskih mreža”
diplomski rad br. 122

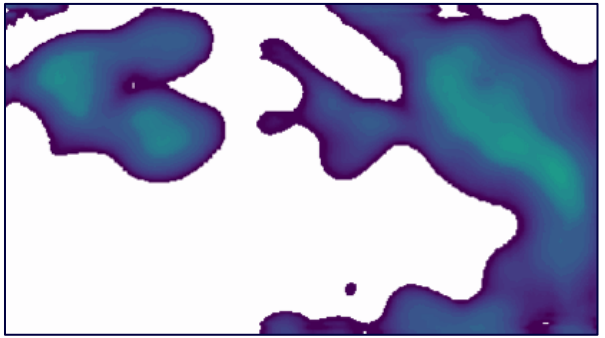
AVL



Sara Orlić, „Weather nowcasting using radar imaging and machine learning”
diplomski rad br. 121



Advensys engineering



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LARES rješenja u praksi

Implementacija rješenja

- **Primjene:**
  - Zgrade HR: **FER** neboder, **King ICT** Buzin, **Klimaoprema** Gradna
  - Zgrade u AT, SI, HU, BA
  - **Vertiv Croatia:** algoritam za back-up H_2 napajanje za data-centre
  - **Rimac Technology:** nova generacija sustava gospodarenja baterijom
  - **Iskon Internet:** koordinirana klimatizacija roja kućanstava
  - **Metal Product:** energetsko čvorište tvorničke hale Breznički Hum
  - **Končar Digital:** prediktivno upravljanje vodoopskrbom

- **FER neboder:** 10000 m^2, 248 ureda, cjelovita IT nadgradnja na postojeći sustav automatizacije zgrade (u pogonu u periodu 2018-2023)

Banjac, Anita; Novak, Hrvoje; Vašak, Mario. Implementation of model predictive indoor climate control for hierarchical building energy management // Control Engineering Practice, 136 (2023), 105536, 17

Automatika i robotika

- LARES – automatika/AI za zelenu tranziciju i industriju
- Uz LARES, na AiR profilu su i 3 međunarodno priznata robotička laboratorija

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  - Solarna energija, Zgrade, Optimizacija sustava, Prediktivno upravljanje, Estimacija, Napredne mreže
- 3. semestar: Universität Brandenburg Cottbus-Senftenberg (BTU)
  - Vodik, Sustavi pohrane energije
- 4. semestar: ECN/FER/BTU/neko treće sveučilište/industrija (Total Energies, Rimac Technology, Končar Digital, Deutsche Luft und Raumfahrt, Fraunhofer…)
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