David E. Bernal Neira

Website: secquoia.github.io/1-bernalde.html
Email: dbernaln@purdue.edu
LinkedIn: bernalde
GitHub: github.com/bernalde
ORCID: 0000-0002-8308-5016

Summary

Principal investigator of the **S**ystems **E**ngineering via **C**lassical and **Qu**antum **O**ptimization for **I**ndustrial **A**pplications (SECQUOIA) research group at Purdue University and Assistant Professor at the Davidson School of Chemical Engineering at that university. Visiting Associate Scientist at the Research Institute of Advanced Computer Science (RIACS) at the Universities Space Research Association (USRA) and the Quantum Artificial Intelligence Laboratory (QuAIL) at the National Air and Space Agency (NASA). Adjunct Professor of Operations Management and Quantum Computing at the Tepper School of Business of Carnegie Mellon University.

Research interests

- Special interest in optimization applications in Chemical Engineering and Process Systems Engineering such as Process Intensification and Energy Systems Optimal Process Synthesis, Design, Operation, and Control.
- Quantum Algorithms for Combinatorial Optimization, with emphasis in Chemical Engineering applications.
- Development and evaluation of novel hardware algorithms for optimization and chemistry.
- Theory and applications of Decision-making Optimization, Machine Learning, and Artificial Intelligence.
- Discrete-Continuous Nonlinear Optimization Solution Algorithms, Theory, and Software.

Education

Carnegie Mellon University — Pittsburgh, PA, USA
Ph.D. in Chemical Engineering, Advisor: Prof. Ignacio E. Grossmann, GPA: 3.92/4.00 — 2017–2021

Universidad de los Andes — Bogotá, Colombia
B.S. in Physics, GPA: 4.62/5.00 — 2011–2018
M.S. in Chemical Engineering, GPA: 4.73/5.00 — 2014–2016
B.S. in Chemical Engineering with Honors - Cum Laude, GPA: 4.62/5.00 — 2010–2014

Experience

Purdue University – Davidson School of Chemical Engineering — West Lafayette, IN, USA
Assistant Professor — 2023-Current

- Principal investigator of the **S**ystems **E**ngineering via **C**lassical and **Qu**antum **O**ptimization for **I**ndustrial **A**pplications (SECQUOIA) research group

NASA - Universities Space Research Association (USRA) — Mountain View, CA, USA
Visiting Scientist at NASA Quantum and Artificial Intelligence Laboratory (QuAIL) — 2023-Current
Visiting Associate Scientist at USRA Research Institute of Advanced Computer Science (RIACS) — 2023-Current
Research Scientist at NASA QuAIL — 2021-2023
Associate Scientist at USRA RIACS — 2021-2023

- Study and design of optimization algorithms that exploit quantum computing for science and engineering

Ph.D. Intern as part of Feynman Quantum Academy NASA QuAIL and USRA RIACS — Summer 2019

- Development and Implementation of Computational Algebraic Geometry and Integer Programming based compiler for Quantum Annealing problem embedding

Carnegie Mellon University – Tepper School of Business — Pittsburgh, PA, USA
Adjunct Professor of Operations Management and Quantum Computing — 2023-Current

- Lecturer of the Quantum Integer Programming and Machine Learning course offered by Electrical and Computers Engineering and the Tepper School of Business

Carnegie Mellon University – Department of Chemical Engineering — Pittsburgh, PA, USA
Visiting Research Scholar — 2021-2022

- Management of Grossmann Research Group meetings
- Maintenance of Mixed-Integer Nonlinear and Generalized Disjunctive Programming Library minlp.org

Ph.D. Student — 2017-2021

- Algorithm development and study for optimization problems with application in chemical, process, and energy systems engineering
- Algorithm development for Mixed-Integer Nonlinear Programming and Generalized Disjunctive Programming
- Study of short-term quantum computing techniques for combinatorial optimization

Visiting Research Scholar — Summer 2015

- Implementation of Mixed-Integer Nonlinear Programming (MINLP) heuristic algorithms in solver DICOPT

ExxonMobil Engineering and Research Company — Clinton, NJ, USA
Ph.D. Intern at Corporate Strategic Research Division — Summer 2020

- Evaluation of quantum computing for solving optimization problems relevant to logistics in oil & gas

Ph.D. Intern at the Process Technology Department — Summer 2018

- Development, implementation, and deployment of a combined heat and power plant with carbon capture technologies optimal operation model

Universidad de los Andes – Department of Chemical Engineering — Bogotá, Colombia
Graduate Teaching and Research Assistant — 2014-2016

- Researcher in the Process and Products Design Group and the Processes Optimization Group

Bayer Technology Services — Leverkusen, Germany
Undergraduate Intern — Spring 2013

- Modeling and automatic implementation of dynamic flooding in distillation columns, and thermodynamic and electrolytic effects in HCl water absorption for acid absorption columns simulation

Awards and Honors

- Arab-American Frontiers Fellowship — 2024
National Academies of Science, Engineering, and Medicine

- Best talk award at the Quantum Computing Applications in Chemical and Biochemical Engineering Workshop 2022
American Institute of Chemical Engineers and Technical University of Denmark

- Finalist for AIChE CAST Directors' Student Presentation Awards — 2020
Computing & Systems Technology Division (CAST) - American Institute of Chemical Engineers

- Mark Dennis Karl Outstanding Teaching Assistant Award — 2019
Chemical Engineering Department - Carnegie Mellon University

- Cum Laude in Chemical Engineering — 2014
Universidad de los Andes

- Alberto Magno Scholarship — 2010-2014

Universidad de los Andes

• Valedictorian 2009

Gimnasio Británico

• First Place National Physics Olympiads Superior Level 2007

Colombian Mathematics and Physics Olympiads

Teaching

Purdue University West Lafayette, IN, USA

Course Instructor at the Davidson School of Chemical Engineering Fall 2023

– CHE 456 Process Dynamics and Control undergraduate course

Carnegie Mellon University Pittsburgh, PA, USA

Lecturer in the Tepper School of Business and Electrical and Computers Engineering Fall 2023

– 47-779 / 47-785 Quantum Integer Programming and Quantum Machine Learning graduate course

Invited Lecturer in the Tepper School of Business and Electrical and Computers Engineering Fall 2022

– 47-779 / 47-785 Quantum Integer Programming and Quantum Machine Learning graduate course

Course Instructor in the Tepper School of Business and Electrical and Computers Engineering Fall 2021

– 47-779 / 47-785 Quantum Integer Programming and Quantum Machine Learning graduate course

Course Instructor in the Tepper School of Business Fall 2020

– 47-779 Quantum Integer Programming graduate course

Graduate Teaching Assistant in the Chemical Engineering Department

– 06-421 Chemical Process Systems Design undergraduate course. Fall 2017, Fall 2018
  • *Mark Dennis Karl Outstanding Teaching Assistant Award*
– 06-720 Advanced Process Systems Engineering graduate course Spring 2018
– 06-805 Special Topics in Chemical Engineering – Disjunctive Programming graduate course Spring 2018

Universidad de los Andes Bogotá, Colombia

Graduate Recitation Leader in the Chemical Engineering Department 2014–2016

– IQUI3040 Chemical Process Optimization 2015-2016
– IQUI2021 Phase and Chemical Equilibrium 2014

Undergraduate Teaching Assistant and Grader 2010–2014

– IQUI3001 Separation Processes and IQUI3040 Chemical Process Optimization in the Chemical Engineering Department
– FISI1518 Physics 1, FISI1528 Physics 2, and FISI2540 Thermodynamics in the Physics Department
– MATE1203 Differential Calculus and MATE2301 Differential Equations in the Mathematics Department

Teaching-related Training

– Future Faculty Program - CMU Eberly Center for Teaching Excellence and Educational Innovation 2019–2022
– Teaching Effectiveness Colloquium - Institute for Operations Research and Management Science 2020

Mentoring

Purdue University West Lafayette, IN, USA
Davidson School of Chemical Engineering 2023-Current

- Yirang Park - Ph.D. Candidate 2023-Current
- Anurag Ramesh - Ph.D. Candidate 2023-Current
- Albert Lee - Ph.D. Candidate 2022-Current
- Carolina Tristán - Postdoctoral Associate 2024-Current
- Amandeep Singh Bhatia - Postdoctoral Associate 2023-Current
- Zedong Peng - Postdoctoral Associate 2023-Current
- Juan Sebastián Rodríguez - Visiting Research Scholar Spring 2024
- Andrés Cabeza - Visiting Research Scholar Fall 2023, Spring 2024
- Pedro Maciel Xavier - Visiting Research Scholar Fall 2023

NASA - Universities Space Research Association Mountain View, CA, USA
Feynmann Quantum Academy 2021-Current

- Farshud Sorourifar - Ph.D. in Chemical Engineering at Ohio State University
- Robin Brown - Ph.D. in Computational and Mathematical Engineering at Stanford University
- Phillip Kerger - Ph.D. in Applied Mathematics and Statistics at Johns Hopkins University
- Pratik Sathe - Ph.D. in Physics at the University of California in Los Angeles
- Dan Zhao - M.Sc. in Computer Science at the New York University
- Diana Chamaki - B.Sc. in Physics at the University of California in Berkeley
- Christopher Um - B.Sc. in Physics at Cornell University

Carnegie Mellon University Pittsburgh, PA, USA
Chemical Engineering M.Sc. students Research 2018-2020

- Yunshan Liu
- Haokun Yang

Chemical Engineering undergraduate students Honors Research 2018-2020

- Felicity Gong
- Rahul Joglekar
- Saeed Syed
- Zhifei Yuliu

Universidad de los Andes Bogotá, Colombia
Chemical Engineering undergraduate students Thesis 2015-2016

- Paola Cristancho
- Hugo Cuellar

Ph.D. Thesis committee member

- Carolina Tristán - Chemical Engineering, Universidad de Santander, Cantabria, Spain. Title: Advancing sustainability in the water-energy nexus. Optimization of reverse electrodialysis energy recovery from salinity gradients
- Phillip Kerger - Applied Mathematics and Statistics, Johns Hopkins University, Baltimore, MD, USA. Title: Topics in Classical and Quantum Optimization: Complexity and Algorithms
- Rodolfo Quintero - Industrial and Systems Engineering, Lehigh University, Bethlehem, PA, USA. Title: Exact Penalization, Lagrangian Relaxation, and Applications to Quantum Computing

– Hsuan-Hao Hsu - Chemical Engineering, Purdue University, West Lafayette, IN, USA. Title: Computational Reaction Discovery Algorithms for Open-Shell and Ionic Organic Species

Other

Master students advised externally

– Pedro Maciel Xavier, Systems and Computing Engineering, Federal University of Rio de Janeiro, Brazil 2024

– Pedro da Silveira Carvalho Ripper, Electrical Engineering, Pontifical Catholic University of Rio de Janeiro, Brazil 2024

Students Awards and Honors

• Andres Cabeza - Best presentation in the AIChE LatinX Virtual Meeting 2023
American Institute of Chemical Engineers LatinX Division

• Haokun Yang - Best submission in the Refining and Petrochemical Plant Modeling and Operations Improvement Session: "Integration of Crude-Oil Scheduling and Refinery Planning By Lagrangean Decomposition Approach" 2018
AIChE Annual Meeting

Short Courses and Workshops Taught

Upcoming

- Master Class: Quantum Computing for CP, AI, and OR, and vice-versa: Quantum-Classical Hybrid Methods for Optimization - CPAIOR, Uppsala, Sweden May 2024
- Workshop: Practical workshop on Quantum Computing for Optimization for Process Systems Engineering - PSE/ESCAPE34, Florence, Italy June 2024

Previous

- Invited Workshop: Quantum Integer Programming - Key Laboratory of Data Analytics and Optimization for Smart Industry, Northeastern University, Shenyang, China Apr. 2024
- Invited Workshop: Quantum Integer Programming - Key Laboratory of Data Analytics and Optimization for Smart Industry, Northeastern University, Shenyang, China Apr. 2024
- Invited Short Course: Quantum Computing in Optimization - Electrical Engineering and Computer Science, Khalifa University, Abu Dhabi, United Arab Emirates Mar. 2024
- Invited Short Course Lectures: 2023 Gene Golub SIAM Summer School on Quantum Computing and Optimization - Lehigh University, Bethlehem, PA, USA Aug. 2023
- Short Course: Mixed-Integer and Disjunctive Optimization Theory, Software, and Algorithms - Institute of Industrial & Systems Engineering, Northeastern University, Shenyang, China Apr. 2019
- Software Workshop: Mathematical Programming in Python/Pyomo - Instituto de Desarrollo y Diseño INGAR CONICET-Universidad Tecnológica Nacional, Santa Fé, Argentina Aug. 2018

Journal Publications

[J1] **D. E. Bernal** and I. E. Grossmann, "Convex mixed-integer nonlinear programs derived from generalized disjunctive programming using cones", *Computational Optimization and Applications*, pp. 1–62, 2024. DOI: 10.1007/s10589-024-00557-9.

[J2] **D. E. Bernal**, C. D. Laird, L. R. Lueg, S. M. Harwood, D. Trenev, and D. Venturelli, "Utilizing modern computer architectures to solve mathematical optimization problems: A survey", *Computers & Chemical Engineering*, p. 108 627, 2024. DOI: 10.1016/j.compchemeng.2024.108627.

[J3] R. Brown, **D. E. Bernal**, D. Venturelli, and M. Pavone, "Copositive programming for mixed-binary quadratic optimization via Ising solvers", *SIAM Journal on Optimization*, vol. 34, no. 2, pp. 1455–1489, 2024. DOI: 10.1137/22M1514581.

[J4] E. G. Rieffel, A. A. Asanjan, M. S. Alam, N. Anand, **D. E. Bernal**, S. Block, L. T. Brady, S. Cotton, Z. G. Izquierdo, S. Grabbe, *et al.*, "Assessing and advancing the potential of quantum computing: A nasa case study", *Future Generation Computer Systems*, 2024.

[J5] P. Kerger, **D. E. Bernal**, Z. Gonzalez Izquierdo, and E. G. Rieffel, "Mind the $\tilde{O}$: Asymptotically Better, but Still Impractical, Quantum Distributed Algorithms", *Algorithms*, vol. 16, no. 7, 2023, ISSN: 1999-4893. DOI: 10.3390/a16070332.

[J6] L. Su, **D. E. Bernal**, I. E. Grossmann, and L. Tang, "Modeling for integrated refinery planning with crude-oil scheduling", *Chemical Engineering Research and Design*, vol. 192, pp. 141–157, 2023. DOI: 10.1016/j.cherd.2023.02.008.

[J7] **D. E. Bernal**, "Coherent simulation with thousands of qubits", *Nature Physics*, 2022. DOI: 10.1038/s41567-022-01772-z.

[J8] **D. E. Bernal**, A. Ajagekar, S. M. Harwood, S. T. Stober, D. Trenev, and F. You, "Perspectives of Quantum Computing for Chemical Engineering", *AIChE Journal*, e17651, 2022. DOI: 10.1002/aic.17651.

[J9] **D. E. Bernal**, Z. Peng, J. Kronqvist, and I. E. Grossmann, "Alternative regularizations for Outer-Approximation algorithms for convex MINLP", *Journal of Global Optimization*, pp. 1–36, 2022. DOI: 10.1007/s10898-022-01178-4.

[J10] R. Quintero, **D. E. Bernal**, T. Terlaky, and L. F. Zuluaga, "Characterization of QUBO reformulations for the maximum k-colorable subgraph problem", *Quantum Information Processing*, vol. 21, no. 3, pp. 1–36, 2022. DOI: 10.1007/s11128-022-03421-z.

[J11] Q. Chen, E. S. Johnson, **D. E. Bernal**, R. Valentin, S. Kale, J. Bates, J. D. Siirola, and I. E. Grossmann, "Pyomo. GDP: an ecosystem for logic based modeling and optimization development", *Optimization and Engineering*, pp. 1–36, 2021. DOI: 10.1007/s11081-021-09601-7.

[J12] S. Harwood, C. Gambella, D. Trenev, A. Simonetto, **D. E. Bernal**, and D. Greenberg, "Formulating and Solving Routing Problems on Quantum Computers", *IEEE Transactions on Quantum Engineering*, 2021. DOI: 10.1109/TQE.2021.3049230.

[J13] D. A. Liñán, **D. E. Bernal**, J. M. Gómez, and L. A. Ricardez-Sandoval, "Optimal synthesis and design of catalytic distillation columns: A rate-based modeling approach", *Chemical Engineering Science*, vol. 231, p. 116 294, 2021. DOI: 10.1016/j.ces.2020.116294.

[J14] H. A. Pedrozo, S. R. Reartes, **D. E. Bernal**, A. Vecchietti, M. S. Díaz, and I. E. Grossmann, "Hybrid model generation for superstructure optimization with Generalized Disjunctive Programming", *Computers & Chemical Engineering*, vol. 154, p. 107 473, 2021. DOI: 10.1016/j.compchemeng.2021.107473.

[J15] **D. E. Bernal**, S. Vigerske, F. Trespalacios, and I. E. Grossmann, "Improving the performance of DICOPT in convex MINLP problems using a feasibility pump", *Optimization Methods and Software*, vol. 35, no. 1, pp. 171–190, 2020. DOI: 10.1080/10556788.2019.1641498.

[J16] T. J. Ikonen, H. Mostafaei, Y. Ye, **D. E. Bernal**, I. E. Grossmann, and I. Harjunkoski, "Large-scale selective maintenance optimization using bathtub-shaped failure rates", *Computers & Chemical Engineering*, vol. 139, p. 106 876, 2020. DOI: 10.1016/j.compchemeng.2020.106876.

[J17] J. Kronqvist, **D. E. Bernal**, and I. E. Grossmann, "Using regularization and second order information in outer approximation for convex MINLP", *Mathematical Programming*, vol. 180, no. 1, pp. 285–310, 2020. DOI: 10.1007/s10107-018-1356-3.

[J18] C. Li, **D. E. Bernal**, K. C. Furman, M. A. Duran, and I. E. Grossmann, "Sample average approximation for stochastic nonconvex mixed integer nonlinear programming via outer-approximation", *Optimization and Engineering*, pp. 1–29, 2020. DOI: 10.1007/s11081-020-09563-2.

[J19] D. A. Liñán, **D. E. Bernal**, L. A. Ricardez-Sandoval, and J. M. Gómez, "Optimal design of superstructures for placing units and streams with multiple and ordered available locations. Part I: A new mathematical framework", *Computers & Chemical Engineering*, p. 106 794, 2020. DOI: 10.1016/j.compchemeng.2020.106794.

[J20] D. A. Liñán, **D. E. Bernal**, L. A. Ricardez-Sandoval, and J. M. Gómez, "Optimal design of superstructures for placing units and streams with multiple and ordered available locations. Part II: Rigorous design of catalytic distillation columns", *Computers & Chemical Engineering*, p. 106 845, 2020. DOI: 10.1016/j.compchemeng.2020.106845.

[J21] H. Yang, **D. E. Bernal**, R. E. Franzoi, F. G. Engineer, K. Kwon, S. Lee, and I. E. Grossmann, "Integration of Crude-Oil Scheduling and Refinery Planning by Lagrangean Decomposition", *Computers & Chemical Engineering*, p. 106 812, 2020. DOI: 10.1016/j.compchemeng.2020.106812.

[J22] J. Kronqvist, **D. E. Bernal**, A. Lundell, and I. E. Grossmann, "A review and comparison of solvers for convex MINLP", *Optimization and Engineering*, vol. 20, no. 2, pp. 397–455, 2019. DOI: 10.1007/s11081-018-9411-8.

[J23] J. Kronqvist, **D. E. Bernal**, A. Lundell, and T. Westerlund, "A center-cut algorithm for quickly obtaining feasible solutions and solving convex MINLP problems", *Computers & Chemical Engineering*, vol. 122, pp. 105–113, 2019. DOI: 10.1016/j.compchemeng.2018.06.019.

[J24] C. L. Lara, **D. E. Bernal**, C. Li, and I. E. Grossmann, "Global optimization algorithm for multi-period design and planning of centralized and distributed manufacturing networks", *Computers & Chemical Engineering*, vol. 127, pp. 295–310, 2019. DOI: 10.1016/j.compchemeng.2019.05.022.

[J25] **D. E. Bernal**, C. Carrillo-Diaz, J. M. Gómez, and L. A. Ricardez-Sandoval, "Simultaneous design and control of catalytic distillation columns using comprehensive rigorous dynamic models", *Industrial & Engineering Chemistry Research*, vol. 57, no. 7, pp. 2587–2608, 2018. DOI: 10.1021/acs.iecr.7b04205.

[J26] L. Su, L. Tang, **D. E. Bernal**, and I. E. Grossmann, "Improved quadratic cuts for convex mixed-integer nonlinear programs", *Computers & Chemical Engineering*, vol. 109, pp. 77–95, 2018, ISSN: 0098-1354. DOI: 10.1016/j.compchemeng.2017.10.011.

[J27] L. Leisman, M. P. Haynes, S. Janowiecki, G. Hallenbeck, G. Józsa, R. Giovanelli, E. A. Adams, **D. E. Bernal**, J. M. Cannon, W. F. Janesh, *et al.*, "(Almost) Dark Galaxies in the ALFALFA Survey: Isolated H i-bearing Ultra-diffuse Galaxies", *The Astrophysical Journal*, vol. 842, no. 2, p. 133, 2017. DOI: 10.3847/1538-4357/aa7575.

Conference Proceedings

[P1] R. A. Brown, D. Venturelli, M. Pavone, and **D. E. Bernal**, "Accelerating continuous variable coherent ising machines via momentum", in *International Conference on the Integration of Constraint Programming, Artificial Intelligence, and Operations Research*, **(CPAIOR2024)**, Springer, 2024, pp. 109–126. DOI: 10.1007/978-3-031-60597-0_8.

[P2] A. F. Cabeza, A. Orjuela, and **D. E. Bernal**, "Analysis of calcium citrate salts as raw material for tributyl citrate bio-plasticizer production: Kinetic modeling, process simulation, and optimization", in *Computer Aided Chemical Engineering*, vol. 53, **(PSE2024/ESCAPE34)**, Elsevier, 2024, pp. 955–960. DOI: 10.1016/B978-0-443-28824-1.50160-5.

[P3] Z. Peng, K. Cao, K. C. Furman, C. Li, I. E. Grossmann, and **D. E. Bernal**, "A convexification-based outer-approximation method for convex and nonconvex minlp", in *Proceedings of the 34th European Symposium on Computer Aided Process Engineering*, **(PSE2024/ESCAPE34)**, Elsevier, vol. 53, 2024. DOI: 10.1016/B978-0-443-28824-1.50536-6.

[P4] F. Sorourifar, D. Chamaki, N. M. Tubman, J. Paulson, and **D. E. Bernal**, "Bayesian optimization priors for efficient variational quantum algorithms", in *Computer Aided Chemical Engineering*, vol. 53, **(PSE2024/ESCAPE34)**, Elsevier, 2024, pp. 3379–3384. DOI: 10.1016/B978-0-443-28824-1.50564-0.

[P5] C. Tristán, M. Fallanza, R. Ibáñez, I. E. Grossmann, and **D. E. Bernal**, "Global optimization via quadratic disjunctive programming for water networks design with energy recovery", in *Computer Aided Chemical Engineering*, vol. 53, **(PSE2024/ESCAPE34)**, Elsevier, 2024, pp. 2161–2166. DOI: 10.1016/B978-0-443-28824-1.50361-6.

[P6] P. M. Xavier, P. Ripper, J. Pulsipher, J. D. Garcia, N. Maculan, and **D. E. Bernal**, "Disjunctive programming meets qubo", in *Computer Aided Chemical Engineering*, vol. 53, **(PSE2024/ESCAPE34)**, Elsevier, 2024, pp. 3433–3438. DOI: 10.1016/B978-0-443-28824-1.50573-1.

[P7] **D. E. Bernal**, Y. Liu, M. L. Bynum, C. D. Laird, J. D. Siirola, and I. E. Grossmann, "Advances in generalized disjunctive and mixed-integer nonlinear programming algorithms and software for superstructure optimization", in *Computer Aided Chemical Engineering*, vol. 49, **(PSE2021+)**, Elsevier, 2022, pp. 1285–1290. DOI: 10.1016/B978-0-323-85159-6.50214-1.

[P8] **D. E. Bernal**, D. Ovalle, D. A. Liñán, L. A. Ricardez-Sandoval, J. M. Gómez, and I. E. Grossmann, "Process superstructure optimization through discrete steepest descent optimization: A gdp analysis and applications in process intensification", in *Computer Aided Chemical Engineering*, vol. 49, **(PSE2021+)**, Elsevier, 2022, pp. 1279–1284. DOI: 10.1016/B978-0-323-85159-6.50213-X.

[P9] **D. E. Bernal**, K. E. Booth, R. Dridi, H. Alghassi, S. Tayur, and D. Venturelli, "Integer programming techniques for minor-embedding in quantum annealers", in *International Conference on Integration of Constraint Programming, Artificial Intelligence, and Operations Research*, **(CPAIOR2020)**, Springer, 2020, pp. 112–129. DOI: 10.1007/978-3-030-58942-4_8.

[P10] **D. E. Bernal**, Q. Chen, F. Gong, and I. E. Grossmann, "Mixed-Integer Nonlinear Decomposition Toolbox for Pyomo (MindtPy)", in *13th International Symposium on Process Systems Engineering (PSE 2018)*, ser. Computer Aided Chemical Engineering, vol. 44, **(PSE2018)**, Elsevier, 2018, pp. 895–900. DOI: 10.1016/B978-0-444-64241-7.50144-0.

[P11] L. Su, L. Tang, **D. E. Bernal**, I. E. Grossmann, and B. Wang, "Integrated scheduling of on-line blending and distribution of oil products in refinery operation", in *13th International Symposium on Process Systems Engineering (PSE 2018)*, ser. Computer Aided Chemical Engineering, vol. 44, **(PSE2018)**, Elsevier, 2018, pp. 1213–1218. DOI: 10.1016/B978-0-444-64241-7.50197-X.

Articles Preprints and Under Review

[S1] **D. E. Bernal**, R. Brown, P. Sathe, F. Wudarski, M. Pavone, E. G. Rieffel, and D. Venturelli, "Benchmarking the Operation of Quantum Heuristics and Ising Machines: Scoring Parameter Setting Strategies on Optimization Applications", Submitted for publication. Available here., 2024.

[S2] E. J. Gustafson, J. Tiihonen, D. Chamaki, F. Sorourifar, J. W. Mullinax, A. C. Li, F. B. Maciejewski, N. P. Sawaya, J. T. Krogel, **D. E. Bernal**, and N. Tubman, "Surrogate optimization of variational quantum circuits", Submitted for publication. Available here., 2024.

[S3] P. Kerger, **D. E. Bernal**, Z. Gonzalez Izquierdo, and E. G. Rieffel, "Classical and Quantum Distributed Algorithms for the Survivable Network Design Problem", Submitted for publication. Available here., 2024.

[S4] J. Wang, Z. Peng, R. Hughes, D. Bhattacharyya, **D. E. Bernal**, and A. W. Dowling, "Measure this, not that: Optimizing the cost and model-based information content of measurements", Submitted for publication. Available here., 2024.

[S5] W. Chaimanowong, **D. E. Bernal**, and F. Cisternas, "Optimizing Product Influence of Shelf Display", Submitted for publication. Available here., 2023.

[S6] T. Lubinski, C. Coffrin, C. McGeoch, P. Sathe, J. Apanavicius, and **D. E. Bernal**, "Optimization applications as quantum performance benchmarks", Submitted for publication. Available here., 2023.

[S7] P. Maciel Xavier, P. Ripper, T. Andrade, J. Dias Garcia, N. Maculan, and **D. E. Bernal**, "QUBO.jl: A Julia Ecosystem for Quadratic Unconstrained Binary Optimization", Submitted for publication. Available here., 2023.

[S8] N. P. Sawaya, D. Marti-Dafcik, Y. Ho, D. P. Tabor, **D. E. Bernal**, A. B. Magann, S. Premaratne, P. Dubey, A. Matsuura, N. Bishop, *et al.*, "HamLib: A library of Hamiltonians for benchmarking quantum algorithms and hardware", Submitted for publication. Available here., 2023.

[S9] **D. E. Bernal**, S. Tayur, and D. Venturelli, "Quantum Integer Programming (QuIP) 47-779: Lecture Notes", Available here., 2020.

Invited Seminars and Lectures

- Invited Seminar: Discrete nonlinear optimization: Modeling and solutions via novel hardware and decomposition algorithms - Key Laboratory of Data Analytics and Optimization for Smart Industry, Northeastern University, Shenyang, China Apr. 2024

- Invited Seminar: Quantum Computing for PSE. Opportunities via Problem Decomposition for Optimization, Machine Learning, and Computational Chemistry - 3rd Process Systems Engineering State of the Art Workshop, Hangzhou, China Apr. 2024
- Seminar: Perspectives on Quantum Computing for Chemical Engineering - Energy and Process Systems Engineering, ETH, Zurich, Switzerland Mar. 2024
- Seminar: Discrete nonlinear optimization: Modeling and solutions via novel hardware and decomposition algorithms - Technology Innovation Institute, Abu Dhabi, United Arab Emirates Mar. 2024
- Invited Seminar: Discrete nonlinear optimization: Modeling and solutions via novel hardware and decomposition algorithms - Industrial and Systems Engineering Research Seminar, Lehigh University, Bethlehem, PA, USA Feb. 2024
- Panelist: Navigating the Intersection of Technology and Society - Purdue Engineering Distinguished Lecture Series of Dean Yannis Yortsos, Purdue University, West Lafayette, IN, USA Video Jan. 2024
- Seminar: Discrete nonlinear optimization: Modeling and solutions via novel hardware and decomposition algorithms - Midwest Quantum Collaboratory Seminar, Purdue University, West Lafayette, IN, USA December. 2023
- Invited Lecture: Perspectives on Quantum Computing for Chemical Engineering - Department of Chemical Engineering, Universidad Nacional de Colombia, Bogotá, Colombia Nov. 2023
- Invited Lecture: Quantum Computing Tutorial - Machine Learning for Engineering, Universidad de los Andes, Bogotá, Colombia Nov. 2023
- Panelist: Artificial Intelligence and Superior Education - AI and Education Congress, Universidad Central, Bogotá, Colombia Oct. 2023
- Seminar: Quantum and Quantum-Inspired Methods for Optimization: Modeling, Algorithms, and Perspectives - Qiskit Fall Fest IBM, Quantum Computing School in Spanish Video Oct. 2023
- Invited Panelist: Quantum Computing - 9th Arab-American Frontiers Symposium, National Academies of Science, Engineering, and Medicine, Doha, Qatar Oct. 2023
- Invited Seminar: Quantum and Quantum-Inspired Methods for Optimization: Modeling, Algorithms, and Perspectives - 9th Arab-American Frontiers Symposium, National Academies of Science, Engineering, and Medicine, Doha, Qatar Oct. 2023
- Seminar: Perspectives on Quantum Computing for Chemical Engineering - IChemE Webinar series Video Oct. 2023
- Invited Seminar: Discrete nonlinear optimization: Modeling and solutions via novel hardware and decomposition algorithms - Industrial Engineering Research Seminar, Purdue University, West Lafayette, IN, USA Sep. 2023
- Panelist: Artificial Intelligence and Superior Education - AI and Education Congress, Fundación Alberto Merani, Bogotá, Colombia Aug. 2023
- Invited Speaker: Discrete nonlinear optimization: Modeling and solutions via novel hardware and decomposition algorithms - Learning from Both Sides Linear and Nonlinear Mixed-Integer Optimization, Institut Mittag-Leffler, Stockholm, Sweden July 2023
- Seminar: Discrete nonlinear optimization: Modeling and solutions via novel hardware and decomposition algorithms - Power Systems Lab, Department of Information Technology and Electrical Engineering, ETH, Zürich, Switzerland Feb. 2023
- Seminar: Perspectives on Quantum Computing for Chemical Engineering: A joint view from Academia and Industry - Sargent Centre of Process Systems Engineering, Imperial College London, London, UK Feb. 2023
- Seminar: Perspectives on Quantum Computing for Chemical Engineering: A joint view from Academia and Industry - CODES Research Group Meeting, University of West Virginia, Morgantown, VA, USA Feb. 2023
- Lecture: Discrete nonlinear optimization: Modeling and solutions via novel hardware and decomposition algorithms - 5th Grid Science Winter School - Los Alamos National Laboratory, Santa Fe, NM, USA Jan. 2023
- Seminar: Perspectives on Quantum Computing for Chemical Engineering: A joint view from Academia and Industry - Sustainable Process Systems Engineering Lab, Institute of Chemical and Bioengineering, ETH, Zürich, Switzerland Dec. 2022
- Seminar: Perspectives on Quantum Computing for Chemical Engineering: A joint view from Academia and Industry - Department of Chemical Engineering, McMaster University, Hamilton, ON, Canada Oct. 2022

- Seminar: Exploiting and Benchmarking Ising Solvers - Quantum Pittsburgh (QPitt) Meetup, Pittsburgh, PA, USA Oct. 2022
- Seminar: Introduction to Quantum Computing and Perspectives of Quantum Computing for Chemical Engineering - Quantum Pittsburgh (QPitt) Meetup, Pittsburgh, PA, USA Jun. 2022
- Plenary Moderator and Panelist: Future of Quantum Computing in Optimization - 2022 CORS/INFORMS International Conference, Vancouver, Canada Jun. 2022
- Seminar: Quantum Computing and Modern Computational Optimization Approaches to Process Systems Engineering - Laboratoire d'Informatique de Paris Nord, Paris, France Apr. 2022
- Seminar: Quantum Computing and Modern Computational Optimization Approaches to Process Systems Engineering (in Spanish) - Universidad de los Andes, Bogotá, Colombia Jan. 2022
- Seminar: Modern Computational Approaches to Nonlinear Discrete Optimization and Process Systems Engineering (in Spanish) - Universidad Nacional de Colombia, Bogotá, Colombia Dec. 2021
- Plenary: Modern Computational Approaches to Nonlinear Discrete Optimization and Process Systems Engineering (in Spanish) - Argentinian Symposium on Industrial Computing and Operations Research, Argentina Video Aug. 2021
- Quantum Computing for Discrete Nonlinear Optimization. Graver Augmented Multiseed Algorithm - Mixed-Integer Nonlinear Programming Virtual Workshop, Computational Optimization Group, Imperial College, London, UK Video Jun. 2021
- Invited Lecture for Modeling and Optimization Group, PSR, Rio de Janeiro, Brazil Apr. 2021
- Seminar: Modern Computational Approaches to Nonlinear Discrete Optimization - Quantum Computing and Mathematical Optimization, Real World Optimization meeting, Gesellschaft für Operations Research and German Aerospace Center, Germany Mar. 2021
- Seminar: Modern Computational Approaches to Nonlinear Discrete Optimization and Applications in Process Systems Engineering - Group for Applied Mathematical Modeling and Analytics, Industrial Engineering Department, University at Buffalo, NY, USA Mar. 2021
- Seminar: Modern Computational Approaches to Nonlinear Discrete Optimization (in Spanish) - Chemical Engineering Department, Universidad de Salamanca, Salamanca, Spain Jan. 2021
- Invited Lecture for Modeling and Optimization Journal Club: Quantum Computing for Optimization - Modeling and Optimization, Amazon, Seattle, WA, USA Jan. 2021
- Invited Lecture for 17-617 Programming Quantum Computers: Quantum Annealing and Ising Model Computation - Institute for Software Research, Carnegie Mellon University, Pittsburgh, PA, USA Dec. 2020
- Seminar: Modern Computational Approaches to Nonlinear Discrete Optimization and their Application to Process Systems Engineering - Chemical Engineering Future Faculty Series Dec. 2020
- Seminar: Modern Computational Approaches to Nonlinear Discrete Optimization and their Application to Process Systems Engineering - Discrete Optimization Talks (DOT) Video Dec. 2020
- Invited Distinguished Speaker: Modern computational approaches to nonlinear discrete optimization - Department of Chemical and Biological Engineering, University of Wisconsin-Madison, Madison, WI, USA Nov. 2020
- Invited Lecture for ID5840 Quantum Integer Programming – Department of Electrical Engineering, Indian Institute of Technology, Madras, India Oct. 2020
- Invited Lecture for 06-720 Advanced Process Systems Engineering: Constraint Programming - Chemical Engineering Department, Carnegie Mellon University, Pittsburgh, PA, USA Feb. 2020
- Invited Lecture for 47-830 Integer Programming: Valid inequalities for Mixed-Integer Programming - Tepper School of Business, Carnegie Mellon University, Pittsburgh, PA, USA Feb. 2019
- Seminar: Incorporating Quadratic Approximations in the Outer-Approximation Method for Convex MINLP - Universidad Nacional del Litoral, Santa Fé, Argentina Aug. 2018
- Incorporating Quadratic Approximations in the Outer-Approximation Method for Convex MINLP - Designing and Implementing Algorithms for Mixed-Integer Nonlinear Optimization, Dagstuhl Seminar 18081, Dagstuhl, Germany Feb. 2018

Invited Conference Presentations

1. Bhatia, A.S., **Bernal, D.E.**. "Federated Hierarchical Tensor Networks: a Collaborative Quantum AI-Driven Framework for Healthcare", *2024 Institute For Operations Research and Management Science (INFORMS) Optimization Society (OS) Meeting.*
2. Lubinski, T., Coffrin, C., McGeoch, C., Sathe, P., Apanavicius, J., **Bernal, D.E.**. "Optimization Applications as Quantum Performance Benchmarks", *2024 INFORMS OS (IOS) Meeting.*
3. **Bernal, D.E.**, Brown, R., Sathe, P., Wudarski, P., Pavone, M., Rieffel, E., Venturelli, D.. "Benchmarking the Operation of Quantum Heuristics and Ising Machines: Scoring Parameter Setting Strategies on Optimization Applications", *2024 IOS Meeting.*
4. **Bernal, D.E.** "Using Quantum and Physics-Inspired Methods for Constrained Optimization: Reformulations, Decomposition Algorithms, Software and Benchmarking", *2023 Institute for Operations Research and Management Sciences (INFORMS) Meeting.*
5. Brown, R., **Bernal, D.E.**, Venturelli, D., Pavone, M. "Accelerating Coherent Continuous Variable Machines Using Momentum", *2023 INFORMS Meeting.*
6. Sorourifar, F., Chamaki, D., Tubman, N, Paulson, J., **Bernal, D.E.** "Specialized Gaussian Process Modifications for Shot-Efficient Quantum-Classical Optimization", *2023 INFORMS Meeting.*
7. Peng, Z., Grossmann, I.E., **Bernal, D.E.** "Mixed-Integer Nonlinear Decomposition Toolbox in Pyomo", *2023 INFORMS Meeting.*
8. **Bernal, D.E.**, Brown, R.A., Venturelli, D., Pavone, M. "Hybrid Classical-Quantum Algorithms for Mixed-Integer Optimization", *2023 Society of Industrial and Applied Mathematics Optimization Meeting (SIAM OP23).*
9. **Bernal, D.E.**, Venturelli, D., Wudarski, F.A., Rieffel, E.G. "Benchmarking the Operation of Quantum Heuristics and Ising Machines: Scoring Parameter Setting Strategies on Real World Optimization Applications", *2022 INFORMS Meeting.*
10. Brown, R.A., **Bernal, D.E.**, Venturelli, D., Pavone, M. "Copositive Optimization via Ising Solvers", *2022 INFORMS Meeting.*
11. Rieffel, E., Kerger, P., **Bernal, D.E.**. "Quantum, quantum-classical hybrid, and distributed quantum algorithms for problems in operations research", *Workshop on Quantum Computing and Operations Research.*
12. **Bernal, D.E.**, Grossmann, I.E. "Easily Solvable Convex Mixed-Integer Nonlinear Programs Derived from Generalized Disjunctive Programming using Cones", *2021 INFORMS Meeting.*
13. Quintero, R.A., **Bernal, D.E.**, Terlaki, T., Zuluaga, L., "Characterization of QUBO reformulations for the maximum k-colorable subgraph problem", *2021 INFORMS Meeting.*
14. **Bernal, D.E.**, Peng, Z., Kronqvist, J., Grossmann, I.E. "Regularization in Decomposition Methods for Global Optimization of Mixed-Integer Nonlinear Programming", *31st European Conference on Operational Research (EURO) 2021.*
15. Li, C., Grossmann, I.E., **Bernal, D.E.**, Furman, K., "Sample Average Approximation for Stochastic Nonconvex Mixed Integer Nonlinear Programming via Outer Approximation", *31st EURO 2021.*
16. Quintero, R.A., **Bernal, D.E.**, Terlaki, T., Zuluaga, L., "Characterization of QUBO reformulations for the maximum k-colorable subgraph problem", *31st EURO 2021.*
17. **Bernal, D.E.**, Kronqvist, J., Lundell, A., Grossmann, I.E. "A Review And Comparison Of Solvers For Convex MINLP", *2020 INFORMS Meeting.*
18. Li, C., **Bernal, D.E.**, Grossmann, I.E., Furman, K., "Sample Average Approximation for Stochastic Nonconvex Mixed Integer Nonlinear Programming via Outer Approximation", *2020 INFORMS Meeting.*
19. **Bernal, D.E.**, Valentin, R., Chen, Q., Grossmann, I.E. "Mixed-integer Nonlinear Decomposition Toolbox for Pyomo MindtPy", *2019 INFORMS Meeting.*
20. Chen, Q., Valentin, R., Kale, S., Bates, J., **Bernal, D.E.**, Bynum, M.L., Siirola, J., Grossmann, I.E. "Advances in Pyomo.GDP: an Ecosystem For Nonlinear Disjunctive Programming Modeling and Optimization Development", *2019 INFORMS Meeting.*
21. **Bernal, D.E.**, Gong, F., Chen, Q., Grossmann, I.E. "Mixed-integer Nonlinear Decomposition Toolbox for Pyomo", *2018 INFORMS Meeting.*

22. **Bernal, D.E.**, Kronqvist, J., Lundell, A., Westerlund, T., Grossmann, I.E. "A Center Cut Algorithm for Quickly Obtaining Feasible Solutions and Solving Convex Mixed Integer Nonlinear Programs", *2018 INFORMS Meeting.*
23. Yang, H., **Bernal, D.E.**, Grossmann, I.E. "Integration of Crude-Oil Scheduling and Refinery Planning By Lagrangean Decomposition Approach", *2018 INFORMS Meeting.*

Fellowships and Scholarships

- Efficient mapping quadratic integer programming problems into qudits-based architectures ($50k) 2024
  Quantum Collaborative Summit Seed funds
- NSF Supplement Award 2234175 Enabling Quantum Computing Platform access ($50k) 2023
  NSF Proposal "Digital design of a network of distributed modular and agile manufacturing systems with optimal supply chain for personalized medical treatments." 2132142
- NSF Supplement Award 2038247 Enabling Quantum Computing Platform access ($50k) 2020
  NSF Proposal "GOALI: Optimal Design and Operation of Reliable Process Systems." 1705372
- Travel Award to attend CRM/DIMACS Workshop on Mixed-Integer Nonlinear Programming 2019
  Centre de recherches mathématiques and Center for Discrete Mathematics and Theoretical Computer Science
- Feynman Quantum Academy - Internship Program 2019
  University Space Research Association (USRA), NASA Quantum and Artificial Intelligence Laboratory
- NSF Travel Award 1838086 2018
  NSF Proposal "GOALI: Optimal Design and Operation of Reliable Process Systems." 1705372
- Travel Award to attend COIN fORgery workshop 2019
  Institute for Mathematics and its Applications and Computational Infrastructure for Operations Research
- Travel Award to attend Dagstuhl seminar on Mixed-Integer Nonlinear Optimization 2018
  NSF Support Grant for Junior Researchers CNS-1257011 and Schloss Dagstuhl Leibniz'Zentrum für Informatik
- Fellowship for Ph.D. in Chemical Engineering 2017
  Center of Advanced Decision-making (CAPD), Chemical Engineering Department, Carnegie Mellon University
- Undergraduate Research Fellow in Astrophysics SURF Cornell-UniAndes 2016
  Cornell University and Universidad de los Andes
- Fellowship for Master of Science Degree in Chemical Engineering 2014
  Chemical Engineering Department, Universidad de los Andes
- Young Engineers Scholarship for International Exchange at Otto-von-Guericke Universität 2012
  German Academic Exchange Service (DAAD), Colombian Science National System (COLCIENCIAS), and Universidad de los Andes
- Alberto Magno Scholarship to Academic Excellence 2009
  Universidad de los Andes

Memberships and Service

Purdue University West Lafayette, IN, USA

Member of the Center of Quantum Technologies (CQT)	2023-Current
Member of the Center of Innovative and Strategic Transformation of Alkane Resources (CISTAR)	2023-Current
Member of the Purdue Quantum Science and Engineering Institute (PQSEI)	2023-Current
Reviewer of the application of the inaugural 38 by 38 award of the College of Engineering	Fall 2024
Member of the Ph.D. recruitment committee at the Davidson School of Chemical Engineering	Fall 2023-Current
Faculty co-advisor of the American Institute of Chemical Engineers (AIChE) student chapter	Fall 2023-Current
Faculty advisor of the Colombian Student Association	Spring 2024-Current

Marshall for the Davidson School of Chemical Engineering graduation Spring 2024

Editorial Activities

- Topic Editor - Frontiers in Computer Science, Experience with Quantum Annealing Computation 2022-2023
- Associate Editor - Frontiers in Chemical Engineering, Computational Methods in Chemical Engineering 2023

Peer Reviewer

- Computers & Chemical Engineering 2020–2024
- IEEE Conference in Design and Control 2024
- Digital Chemical Engineering 2022–2023
- Optimization Letters 2021–2022
- ACM Transactions in Quantum Computing 2023
- Nature Physics 2022
- Quantum Information Processing 2022
- Operational Research 2022
- Frontiers of Sustainability 2022
- IEEE Conference on Decision and Control 2022
- Optimization & Engineering 2019–2021
- Journal of Optimization Theory and Applications 2021
- Quantum Machine Intelligence 2021
- Current Opinion in Chemical Engineering 2021
- Mathematical Programming 2020
- Journal of Global Optimization 2019–2021
- Chemical Engineering Journal 2019
- American Control Conference 2020

Professional Societies Activites

American Institute of Chemical Engineers (AIChE) Member since 2014

- Session co-chair at Annual meeting on advances in process design 10A session 2024
- Organizer for the Workshop of Quantum Computing and Artificial Intelligence for Chemical and Biochemical Engineering Applications - AIChE and DTU 2024
- Session chair at AIChE Midwest Regional Meeting on Machine Learning and Optimizations 2024
- Scientific committee member for the Workshop of Quantum Computing for Chemical and Biochemical Engineering Applications - AIChE and DTU 2023
- Session chair at Workshop of Quantum Computing for Chemical and Biochemical Engineering Applications session on Emerging QC Applications for Engineers 2023
- Jury for the best poster in the Chemical Engineering division for the forum for Latin American chemistry community conference LatinXChemE 2021

Institute for Operations Research and Management Science (INFORMS) Member since 2017

- Program Committee member for Computational Optimization on INFORMS Optimization Society Meeting - Rice University 2024
- Session chair at INFORMS Annual Meeting session on Hybrid Quantum-Classical methods for Optimization and Sampling 2022
- Session chair at INFORMS Annual Meeting session on Integer Programming 2021
- Session chair at INFORMS Annual Meeting session on Pyomo 2019

Society for Industrial and Applied Mathematics (SIAM) Member since 2020

- Organizer of mini-symposium for Quantum Computing in Optimization - SIAM OP meeting 2023

American Physics Society (APS) Member since 2021

- Session chair at APS March Meeting session on Quantum Network Algorithms and Analysis 2023
- Sorting of talks for the Division of Quantum Information at the American Physics Society (APS) March Meeting 2022

Carnegie Mellon University Pittsburgh, PA, USA

Member of the Pittsburgh Quantum Institute (PQI) 2019-Current

Chemical Engineering LatinX and Hispanics Graduate Student Recruiting Session Organizer 2021

SHPE Annual Meeting CMU College of Engineering Graduate Student Recruiting Volunteer 2020

Liaison of the CMU Quantum Computing group for the Pittsburgh Quantum Institute (PQI) 2017–2021

Conference chair and organizer of YinzOR Student Conference 2017

Other

Panelist for Workshop on Quantum Computing and Operations Research - Fields Institute in Toronto 2022

Jury for the best undergraduate graduation project at Universidad de los Andes Chemical Engineering 2021

Moderator on the discussion about Decomposition techniques at MINLP Virtual Workshop 2021

Software Products

- **MindtPy** (Developer): Open-source decomposition toolkit for Mixed-Integer Nonlinear Programming
- **Stochastic-Benchmark** (Developer): Open-source benchmarking tool for stochastic optimization solvers
- **toQUBO.jl** (Originator): Open-source library for reformulation of Mathematical Programs into Quadratic Unconstrained Binary Optimization in Julia
- **QUBOTools.jl** (Originator): Open-source Tools for Quadratic Unconstrained Binary Optimization models analysis in Julia
- **QUBODrivers.jl** (Originator): Interface for classical and quantum annealing solvers in Julia
- **GDPLib** (Contributor): Open-source library of Generalized Disjunctive Programming models in Pyomo
- **GDPOpt** (Contributor): Open-source solver for Generalized Disjunctive Programming in Pyomo
- **DICOPT** (Contributor): Commercial solver for Mixed-Integer Nonlinear Programming in GAMS

Languages

	Comprehension		Speaking		Written Expression
	Listening	Reading	Oral Interaction	Oral Expression	
Spanish	Native Speaker				
English	C2	C2	C1	C1	C1
	TOEFL 115/120				
German	C1	C1	C1	B2	B2
	Test DaF 4.5/5				
French	A2	A2	A2	A2	A1
	Test Delf A2 74.5/100				

Level A1/A2 Basic User – B1/B2 Independent User – C1/C2 Proficient User
Common European Framework of Reference for Languages